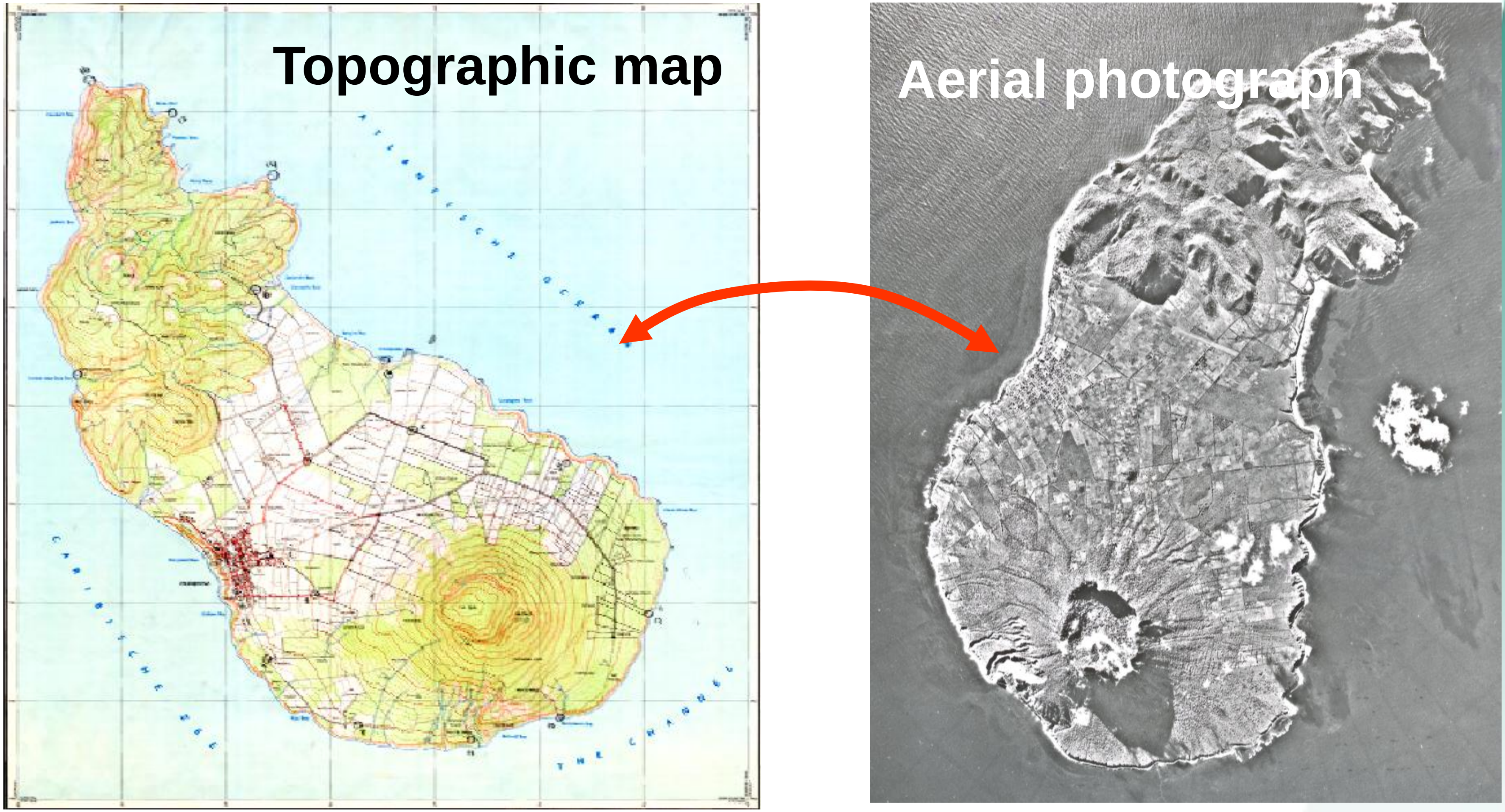
Introduction on Photogrammetry

By: Koert Sijmons


Topographic map
Aerial photograph

Difference between map and photo

MAP	PHOTOGRAPH
Orthogonal projection.	Central perspective projection
Uniform scale.	Variable scales.
Terrain relief without distortion (contour lines).	Relief displacement in the image
All objects are represented also the non visible	Only objects that are visible.
An abstract representation	Is a real representation of the earth surface, no legend needed.

Cont.

Difference between map and photo

MAP

- Representation geometrically correct
- Elements appear displaced in its real position and in different shapes, due to the generalization process.

PHOTOGRAPH

- Representation geometrically not correct
- Objects appear displaced due to geometric distortions.

Cont.

Basic principles of Photogrammetry

Photogrammetry is the science and technology of obtaining spatial measurements and other geometrically reliable derived products from photographs.

Photogrammetric analysis procedures can range from:

Obtaining approximate distances, areas, and elevations using hardcopy photographic products with unsophisticated equipment

Geometric concepts to generating precise digital elevation Models (DEMs), Orthophotos,and thematic GIS data

Cont.

Introduction

The terms digital and softcopy photogrammetry are interchangeable to refer to any photogrammetric operation involving the use of digital raster photographic image data rather than hardcopy images.

Digital photogrammetry is changing rapidly and forms the basis for most current photogrammetric operations.

However, the same basic geometry principles apply to traditional hardcopy (analog) and softcopy (digital) procedures.

Cont. →

Introduction

Mapping from aerial photographs can take on numerous forms and can employ either hardcopy or softcopy approaches.

Traditionally, topographic maps have been produced from hardcopy stereo-pairs in a stereo-plotter device.

A stereo-plotter is designed to transfer map information without distortions, from stereo photographs.

A similar device can be used to transfer image information, with distortions removed, in the form of an Orthophoto.

Cont.

Introduction

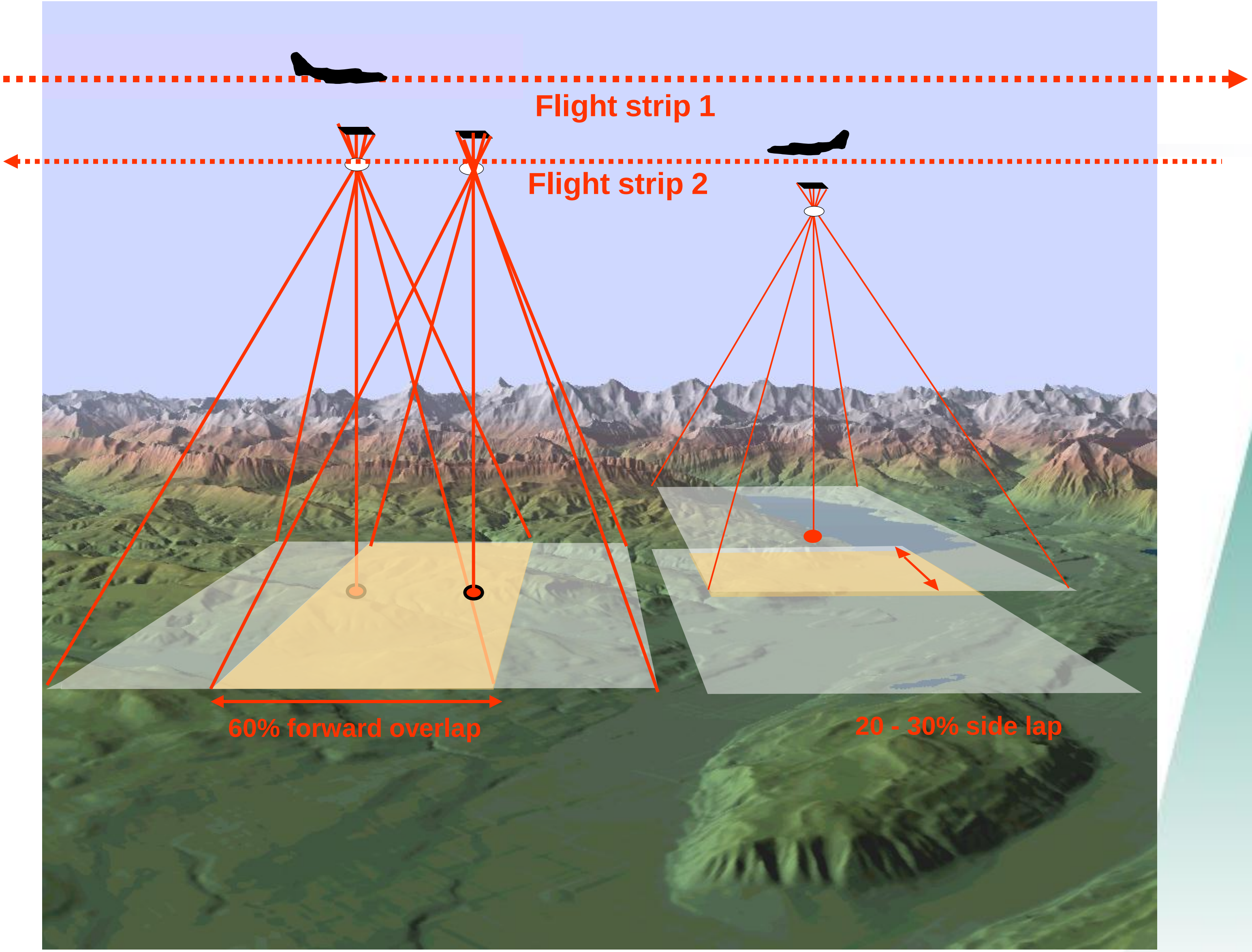
Orthophotos combine the geometric utility of a map with the extra “real-world image” information provided by a photograph.

The process of creating an Orthophoto depends on the existence of a reliable DEM for the area being mapped. The DEM is usually prepared photogrammetrically as well.

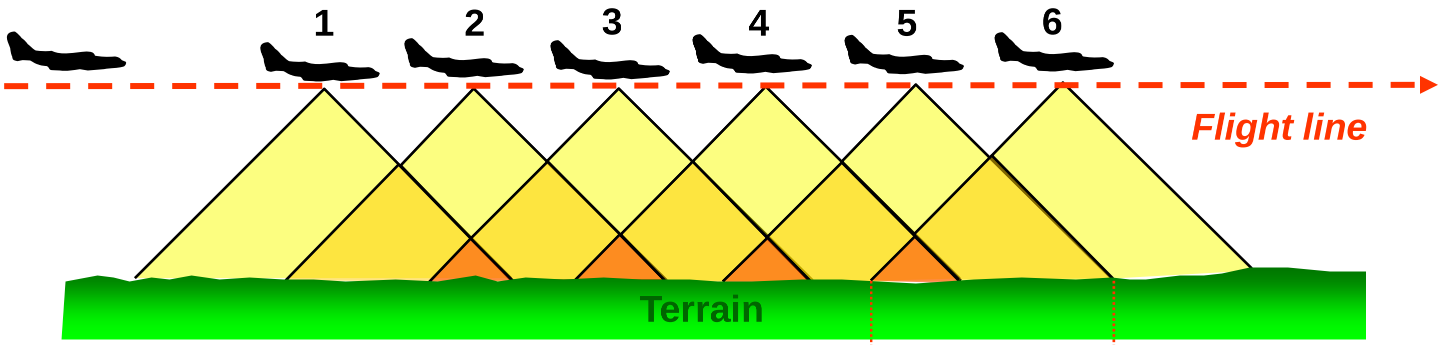
A digital photogrammetric workstation generally provide the Integrated functionality for such tasks as generating:

DEMs, digital Orthophotos, perspective views, and “fly-throughs” simulations, as well as the extraction of spatially referenced GIS data in two or three dimensions

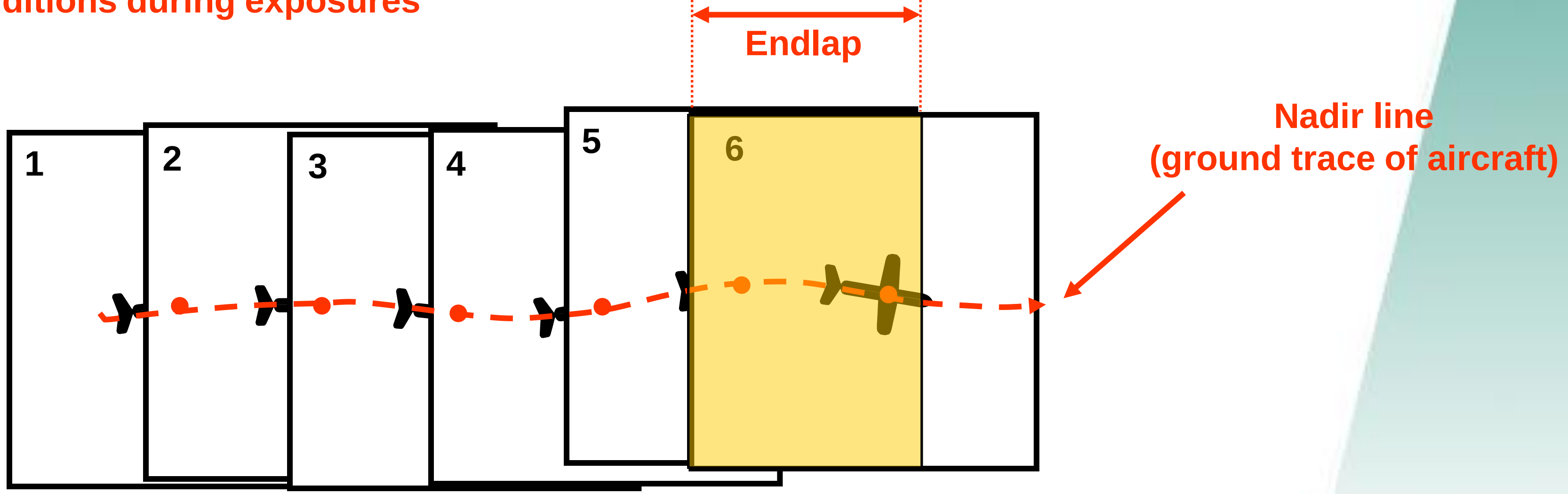
Introduction


Flight strip 1
Flight strip 2
60% forward overlap
20 - 30% side lap

Photographic coverage along a flight strip

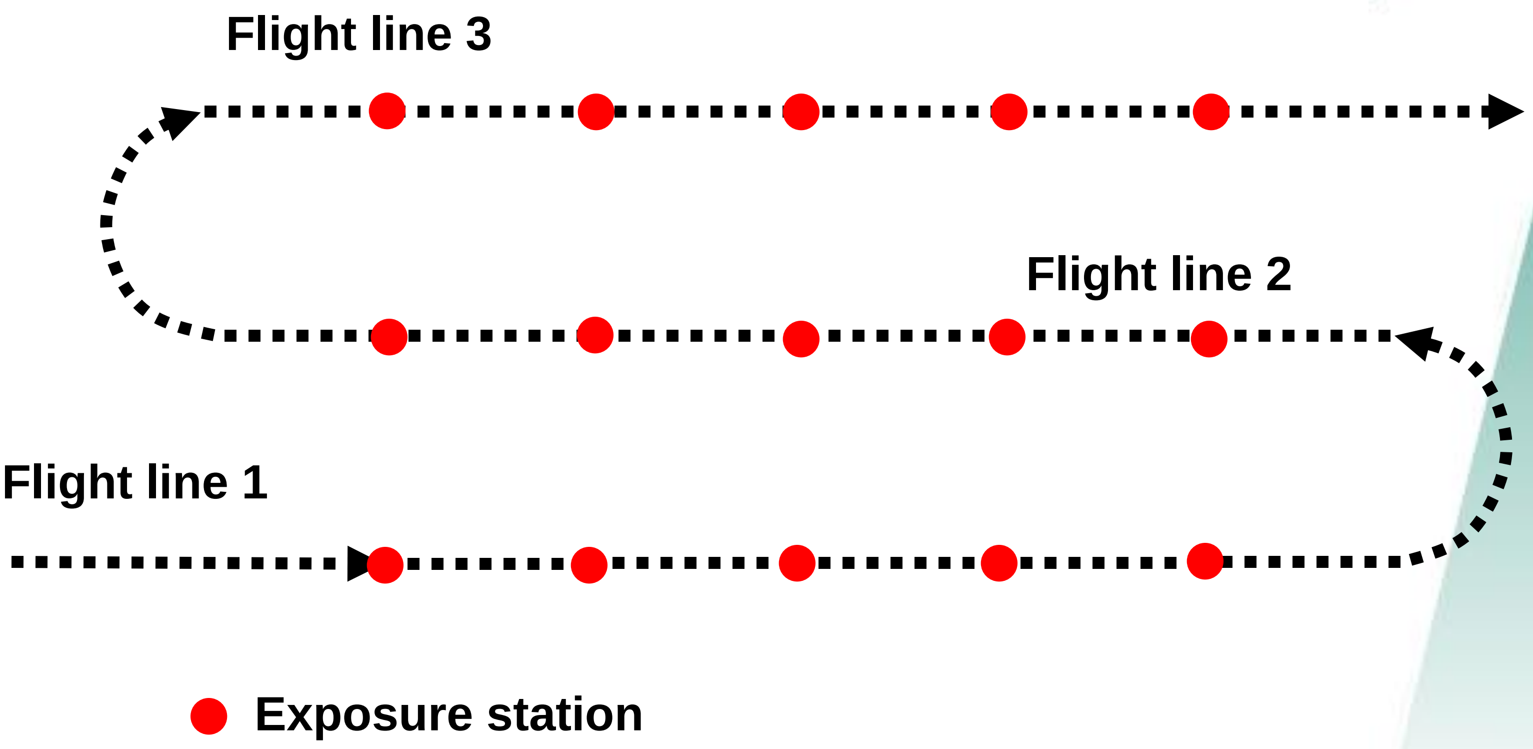


Conditions during exposures



Resulting photography

Flight paths (Photo run)



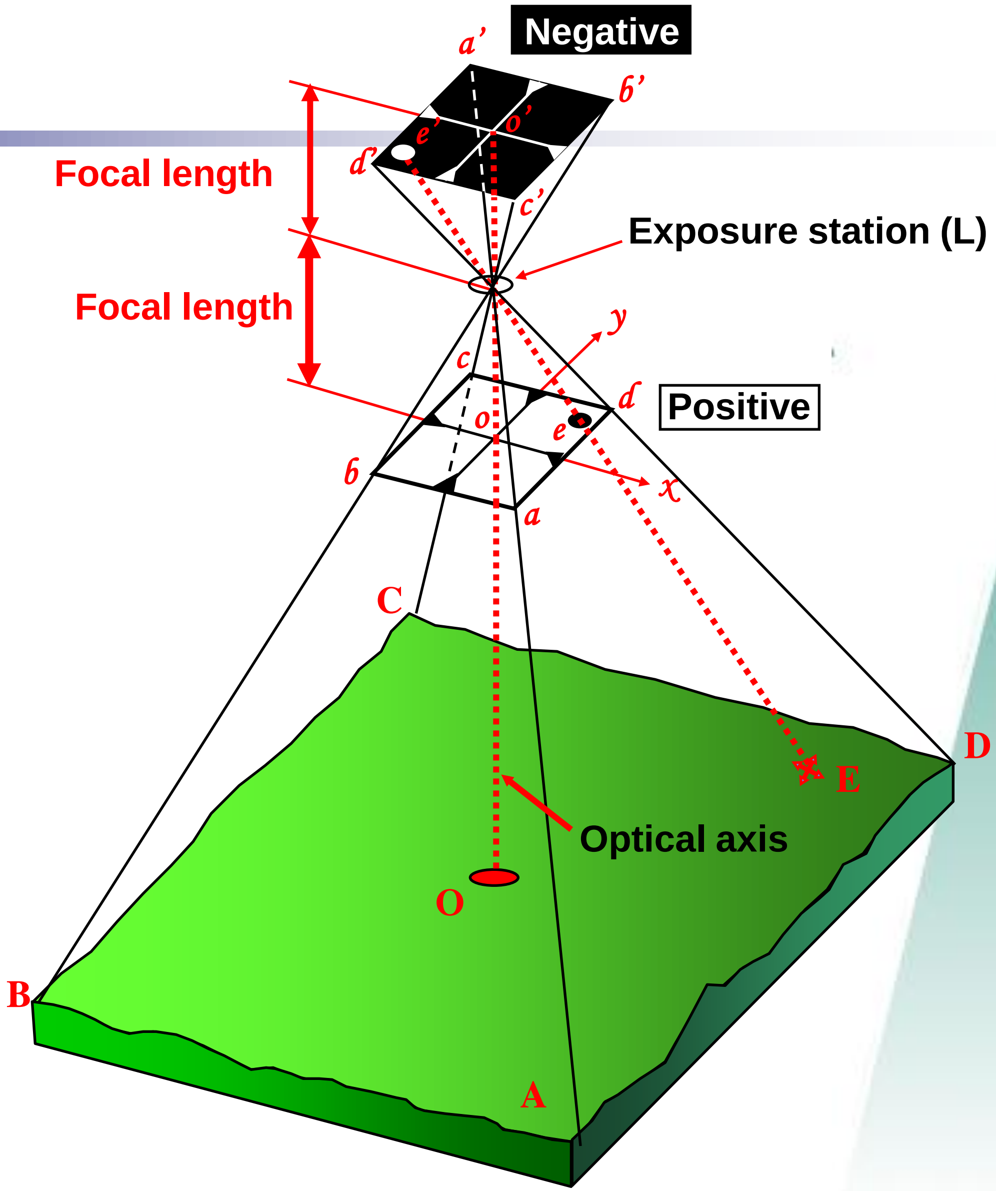
Flight line 3

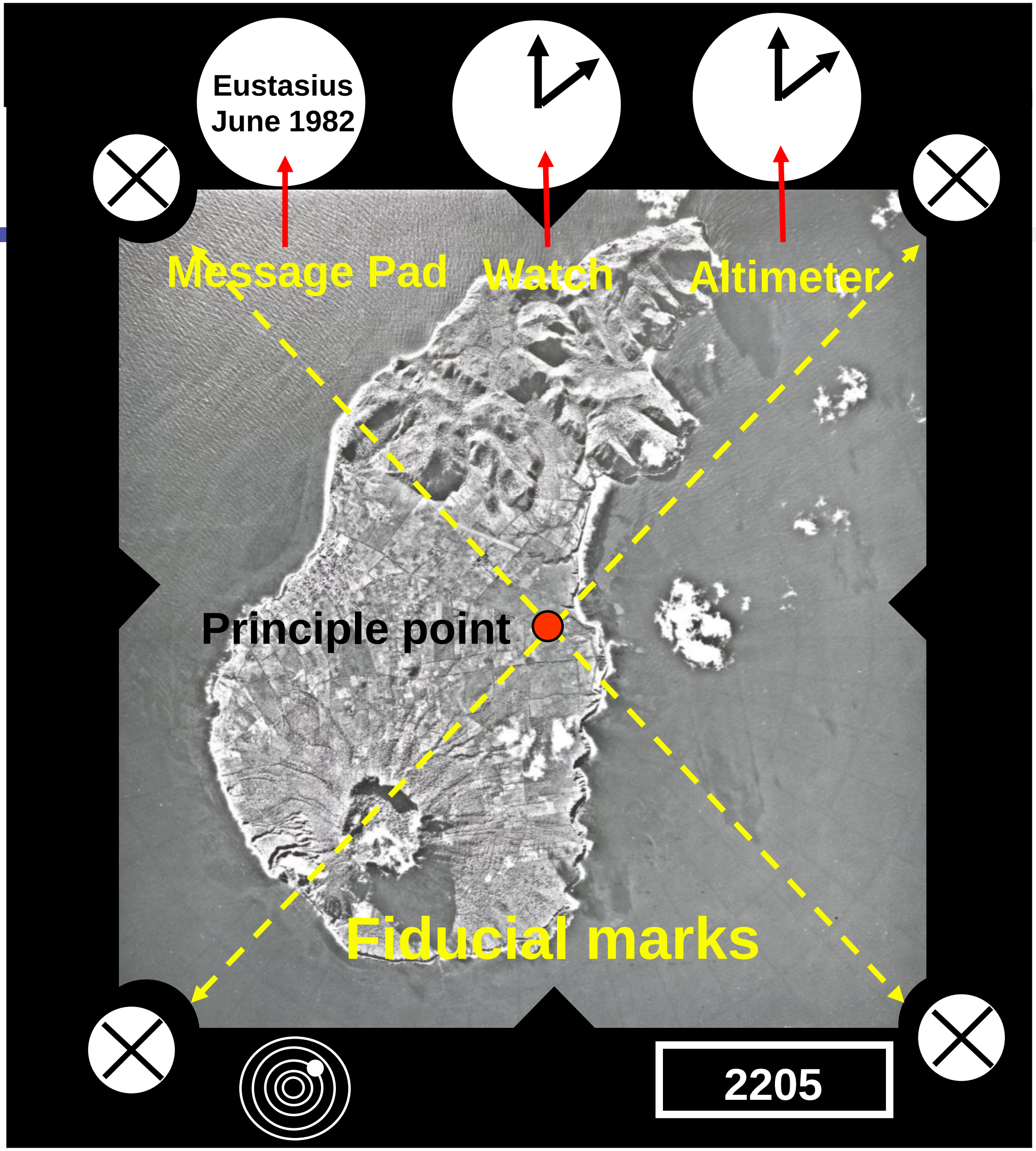
Flight line 2

Flight line 1

● Exposure station

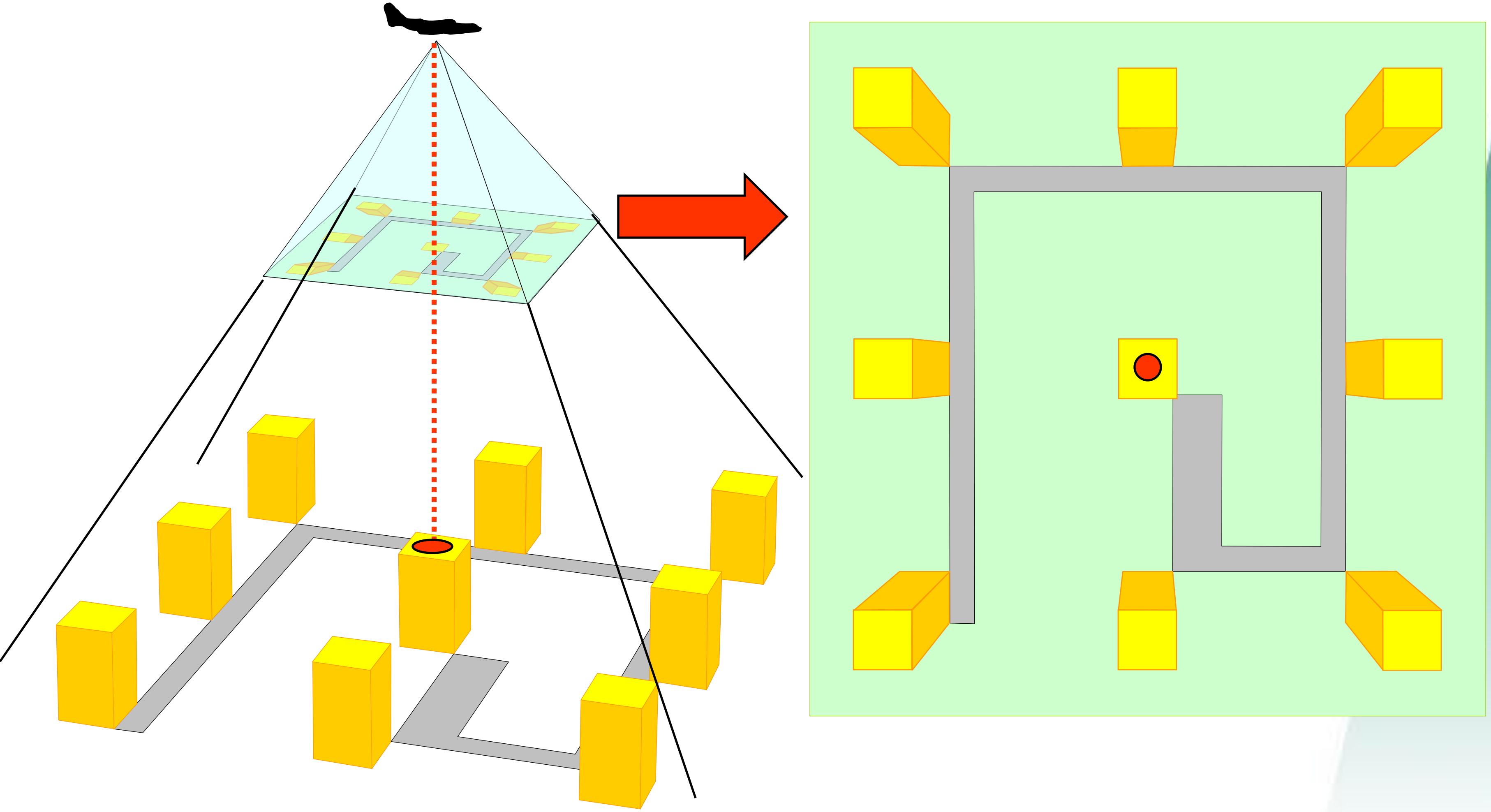
Geometric elements of an aerial photo



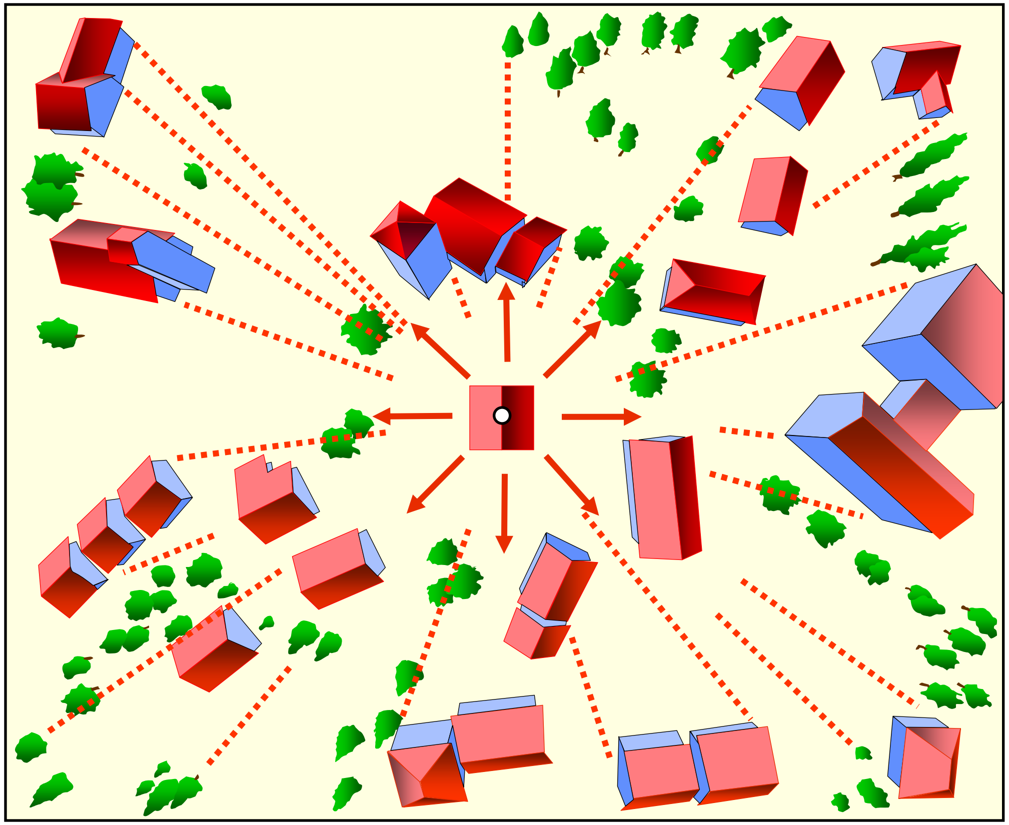

Eustasius
June 1982
Message Pad
Watch
Altimeter
Principle point
Fiducial marks
2205

Photography

- central projection

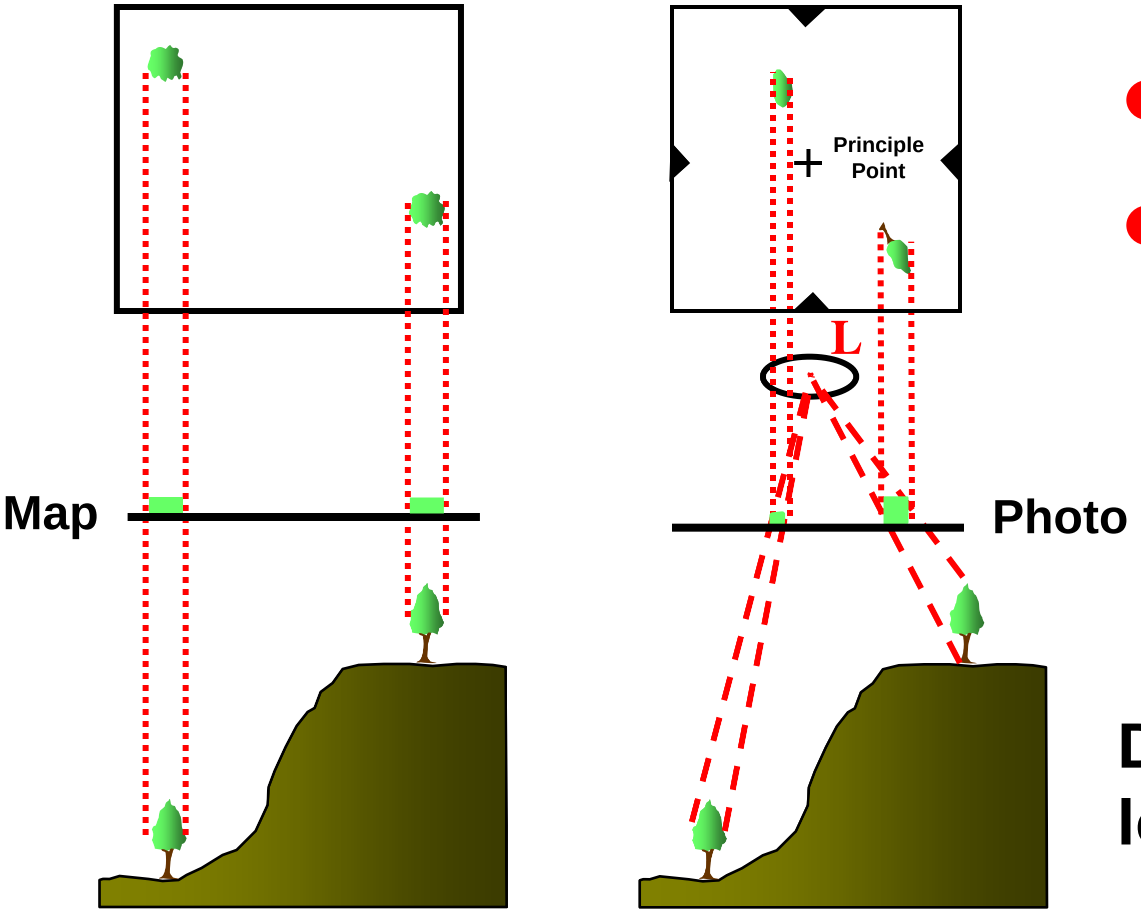


Central perspective



Geometry of Map and Photo

Orthogonal projection **Central Perspective projection**



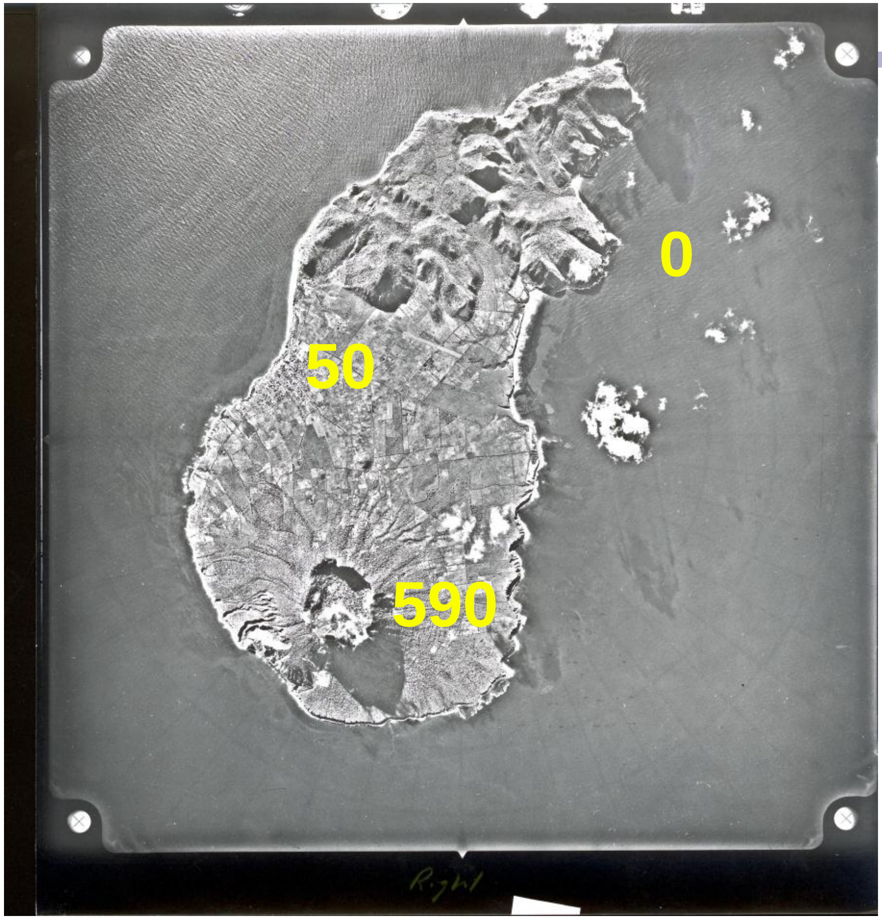
- Varied scale
- Relief displacement

Result in:

Different size, shape and location of static objects

Scale

$$S = \frac{H - h}{f}$$



Closer to the camera = larger scale

S = scale
f = focal length (15.323 cm)
H = flying height (6200 mtr.)
h = local terrain height

Scale at sea level (0 mtr.):

1:40.462

Scale at 50 mtr. Terrain elevation:

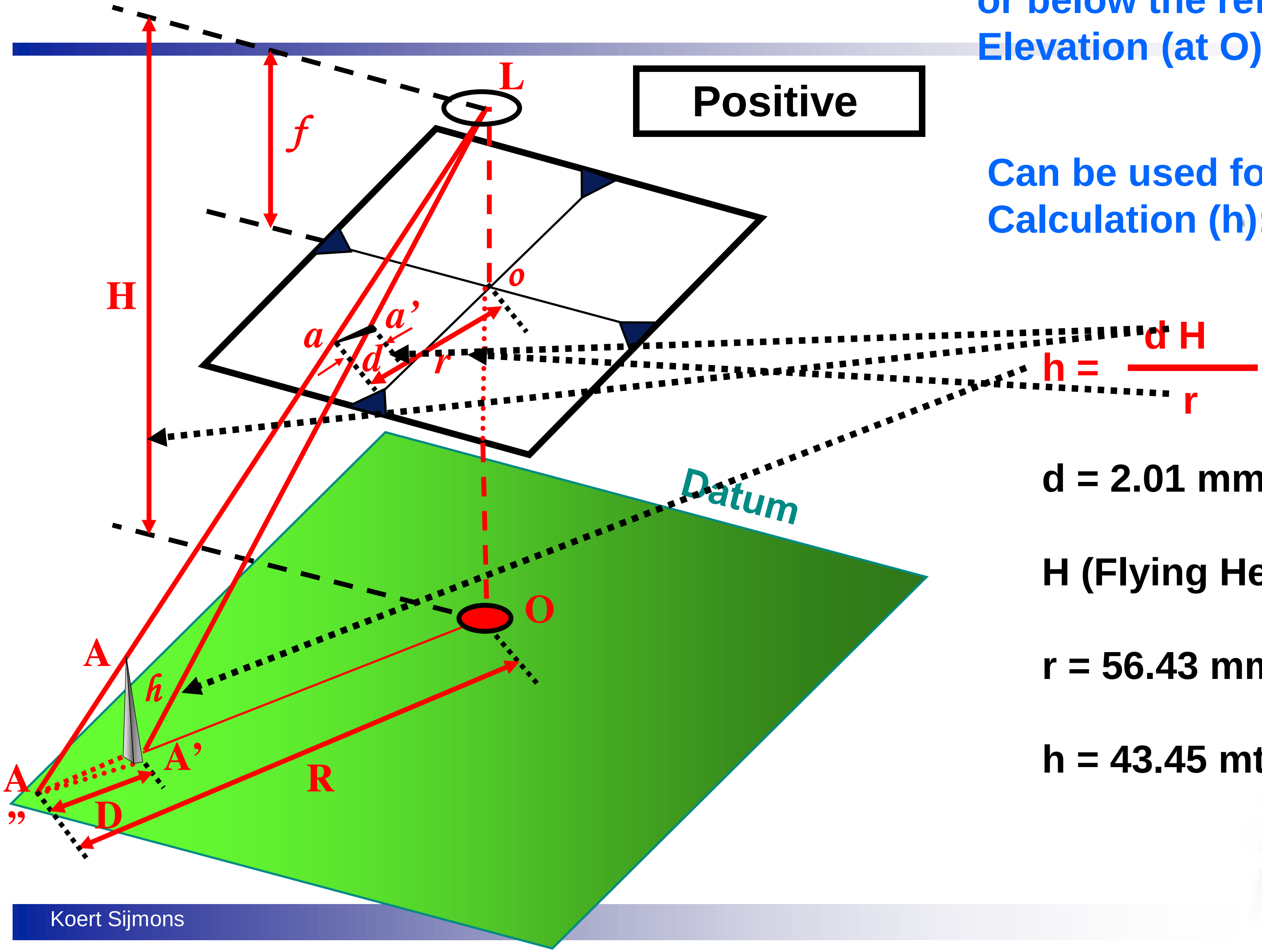
1:40.136

Scale at top volcano (590 mtr.)

1:36.612

Relief displacement

Occurs for terrain points Whose elevation is above or below the reference Elevation (at O).



Can be used for height Calculation (h):

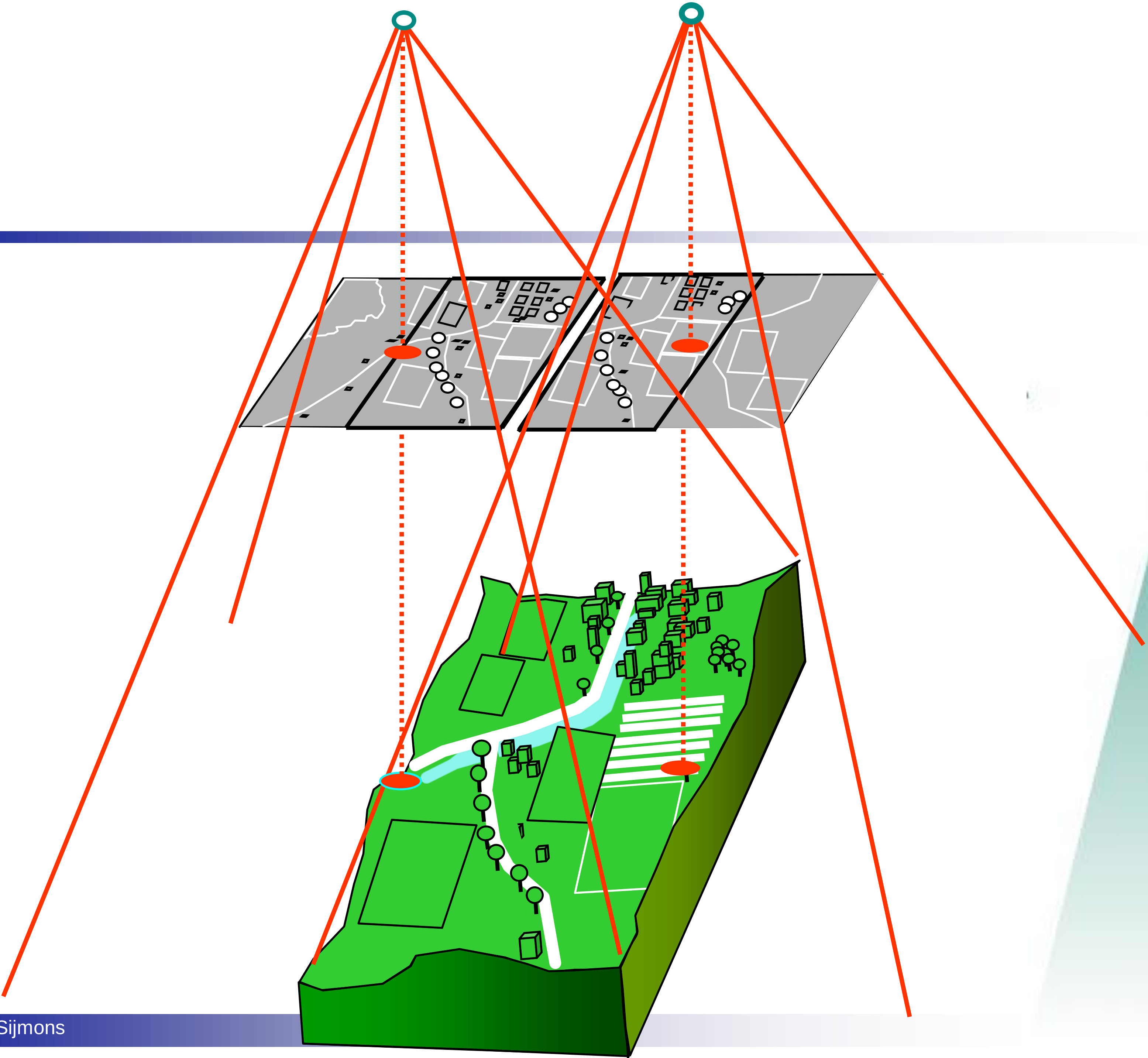
$$h = \frac{d\,H}{r}$$

d = 2.01 mm.

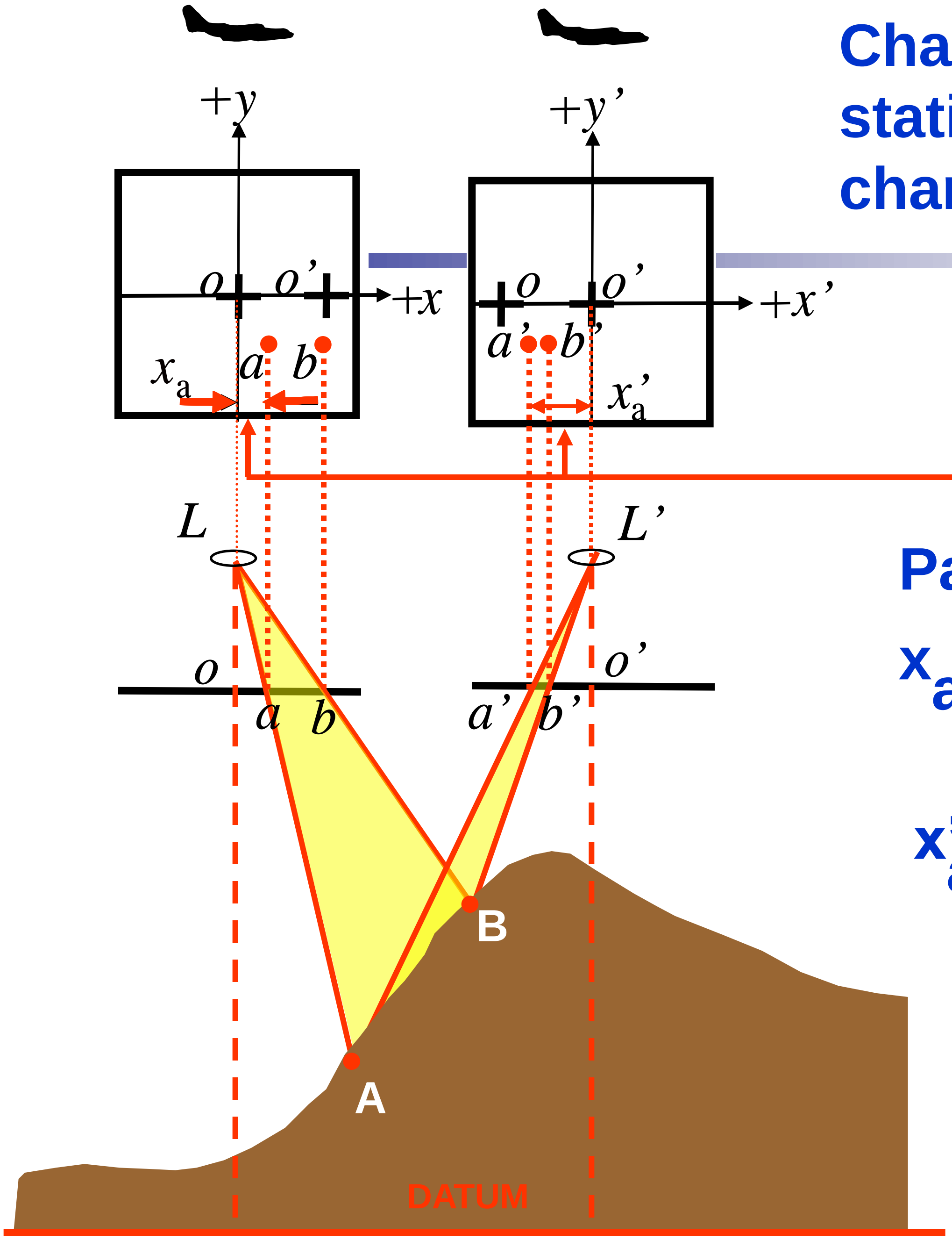
H (Flying Height) = 1220 mtr.

r = 56.43 mm.

h = 43.45 mtr.



Change in positions of stationary objects caused by a change in viewing position



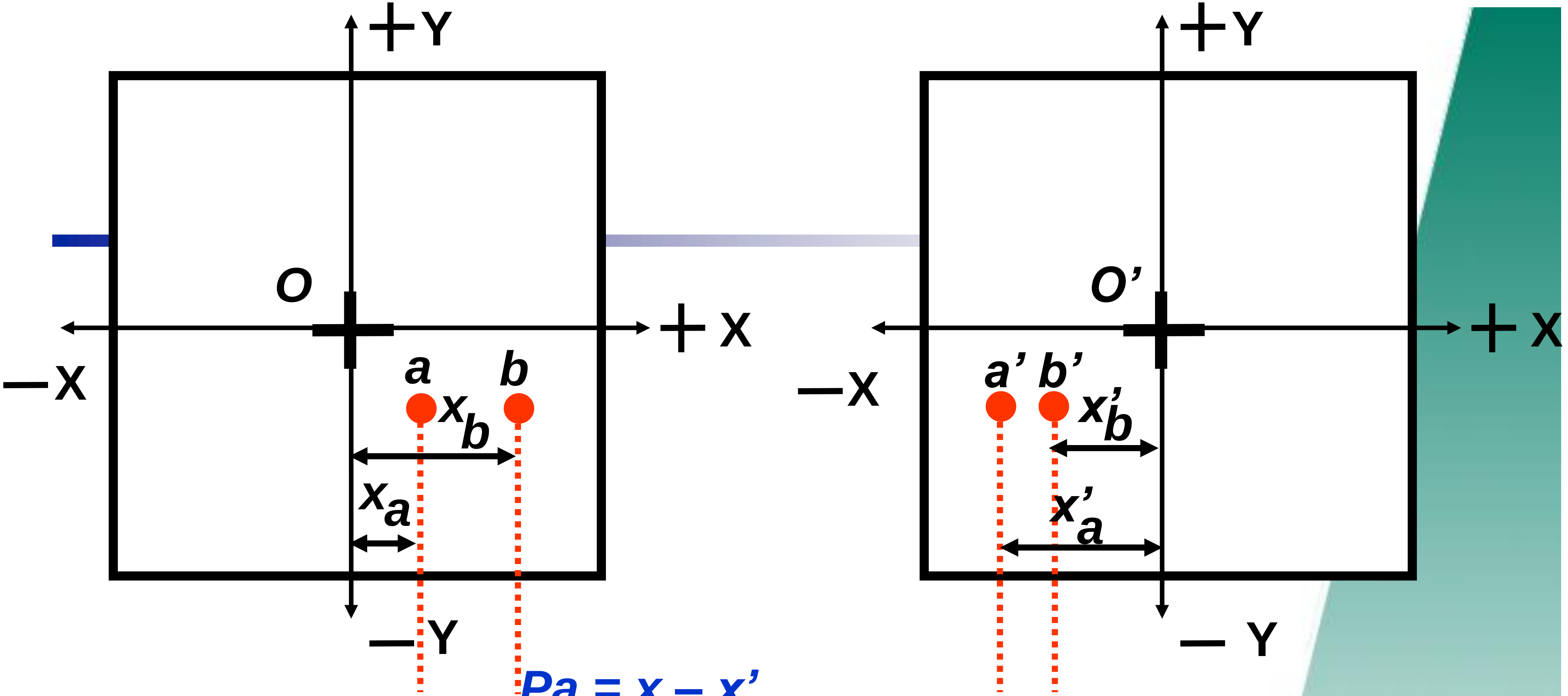
Parallax of point A

$$P_a = \boxed{x_a - x'_a}$$

P_a = the parallax of point A

x_a = The measured x coordinate of image a on the left photo

x'_a = the x coordinate of image a' on the right photo



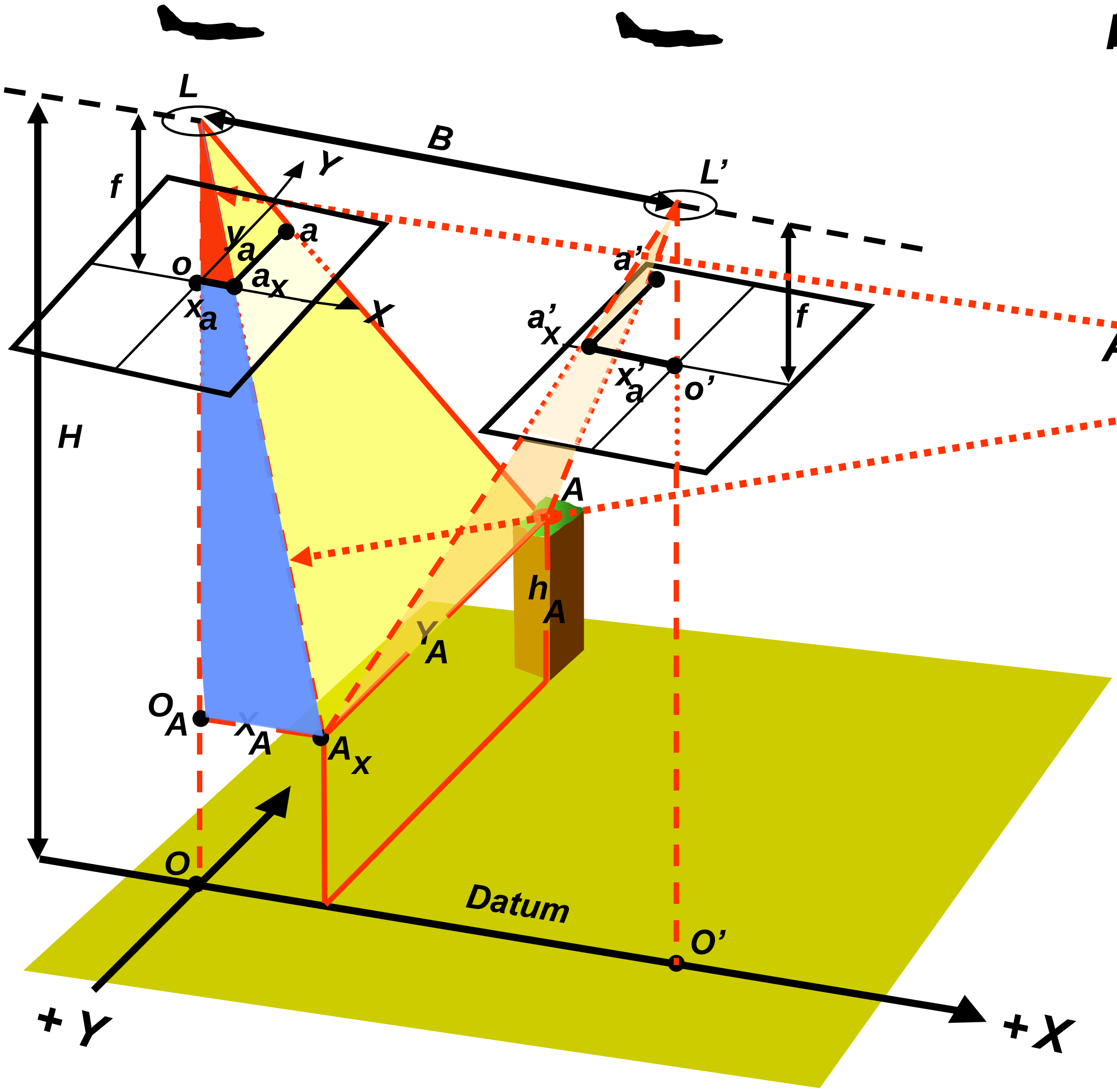
$$Pa = x_a - x'_a$$

$$Pa = 54.61 - (-59.45) = 114.06 \text{ mm}$$

$$Pb = x_b - x'_b$$

$$\Delta P = 12.00$$

$$Pb = 98.67 - (-27.39) = 126.06 \text{ mm}$$



[illegible]

$$\frac{P_a}{f} = \frac{B}{H - h_A}$$

$$H - h_A = \frac{Bf}{P_a}$$

Also from similar triangles:

LOA_x and Loa_x

$$\frac{X_A}{H - h_A} = \frac{x_a}{f}$$

From which:

$$X_A = \frac{x_a(H - h_A)}{f}$$

$$X_A = B\frac{x_a}{p_a}$$

$$Y_A = B\frac{y_a}{p_a}$$

$$X_A = B\frac{x_a}{p_a} \qquad Y_A = B\frac{y_a}{p_a}$$

→ *Parallax equations*

X and Y are ground coordinates of a point with respect to an arbitrary coordinate system whose origin is vertically below the left exposure station and with positive X in the direction of flight

p Is the parallax of the point in question

x and y are the photocoordinates of point *a* on the left-hand photo

The major assumptions made in the derivation of these equations are that the photos are truly vertical and that they are taken from the same flying height.

Aerial Photo Concept

Digital Orthophotos are generated from the same type of Aerial photo as conventional hardcopy Orthophotography.

The difference lies in the scanning of the airphoto, converting the photo to a digital image product that will be manipulated and processed with a computer.

Cont. ➡

Aerial Photo Concepts

The relationship between photo scale, scanning resolution and final scale must be considered.

Final resolution of the Orthophoto product is based on the application that the Orthophotos are being used for, and also the limitations of disk space that may be encountered during the project.

It is not always beneficial to scan an airphoto at the highest number of dots per inch (DPI), if the application does not warrant such high resolution.

Cont. →

Aerial Photo Concepts

A simple equation can be used to calculate the scanning resolution necessary based on the original scale, final output pixel size and the size of the hardcopy photo.

The equation is:

$$r_s = \frac{d}{W * p} * 2,54 \text{ cm/inch}$$

where:

r_s = scanning resolution (DPI)

d = Foot print size (cm)

W = photo size (cm)

p = output pixel size (cm)

Cont.

Aerial Photo Concepts

Example:

A photo is 9 inches (22.86 cm) across, and covers a ground distance of 8 Km. The final resolution required is 3 meter the scanning resolution in dots per inch (DPI) would be:

$$r_s = \frac{800000 \text{ cm}}{22.86 \text{ cm} * 300 \text{ cm}} * 2.54 \text{ cm/inch} = 296 \text{ DPI}$$

Cont. ➡

Aerial Photo Concepts

The scanning resolution can also be determined from the photo scale, without having calculate the ground distance. photo scale is more commonly quoted in the aerial survey report.

From the previous mentioned equation: $r_s = \frac{d}{W * p}$

we derive:

$$r_s = \frac{d}{W} * \frac{2.54}{p} = S * \frac{2.54}{p}$$

where S = photo scale

Cont. →

Aerial Photo Concepts

For example, a typical aerial survey might consist of photos at 1:4,800 scale. The desired output resolution for the orthophotos is approx. 30 cm. For 22.86 cm airphoto, a reasonable scanning resolution would be:

$$r_s = S * \frac{2.54}{p} = 4800 * \frac{2.54}{30} = 406 \text{ DPI}$$

Aerial Photo Concepts

The St. Eustasius demonstration dataset was flown at an average photoscale of 1:40,500

The photos are 22.86 cm x 22.86 cm.

We want a ground resolution of 3m., so we must calculate the scanning resolution.

$$r_s = S * \frac{2.54}{p} = 40.500 * \frac{2.54}{300} = 342.9 \text{ DPI}$$

Photogrammetric Triangulation

What is it?

- **Increasing the density of whatever ground control you have; called "Control Point Extension"**

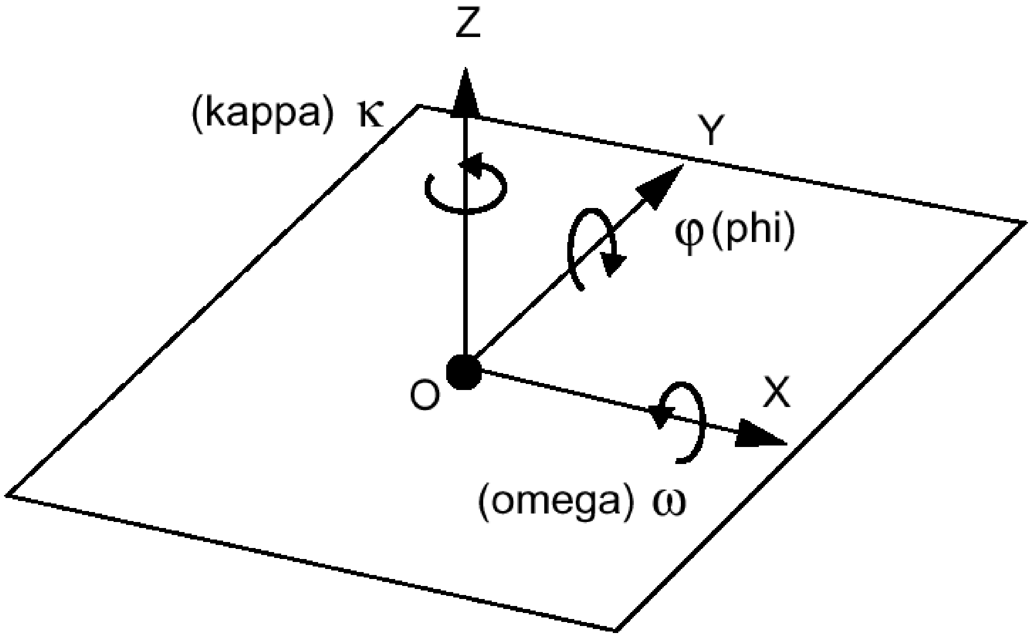
What does it do?

- **Computes coordinate values for any point measured on two or more images (tie points)**

- **Computes positions and orientation for each camera station**

Cont.

Photogrammetric Triangulation



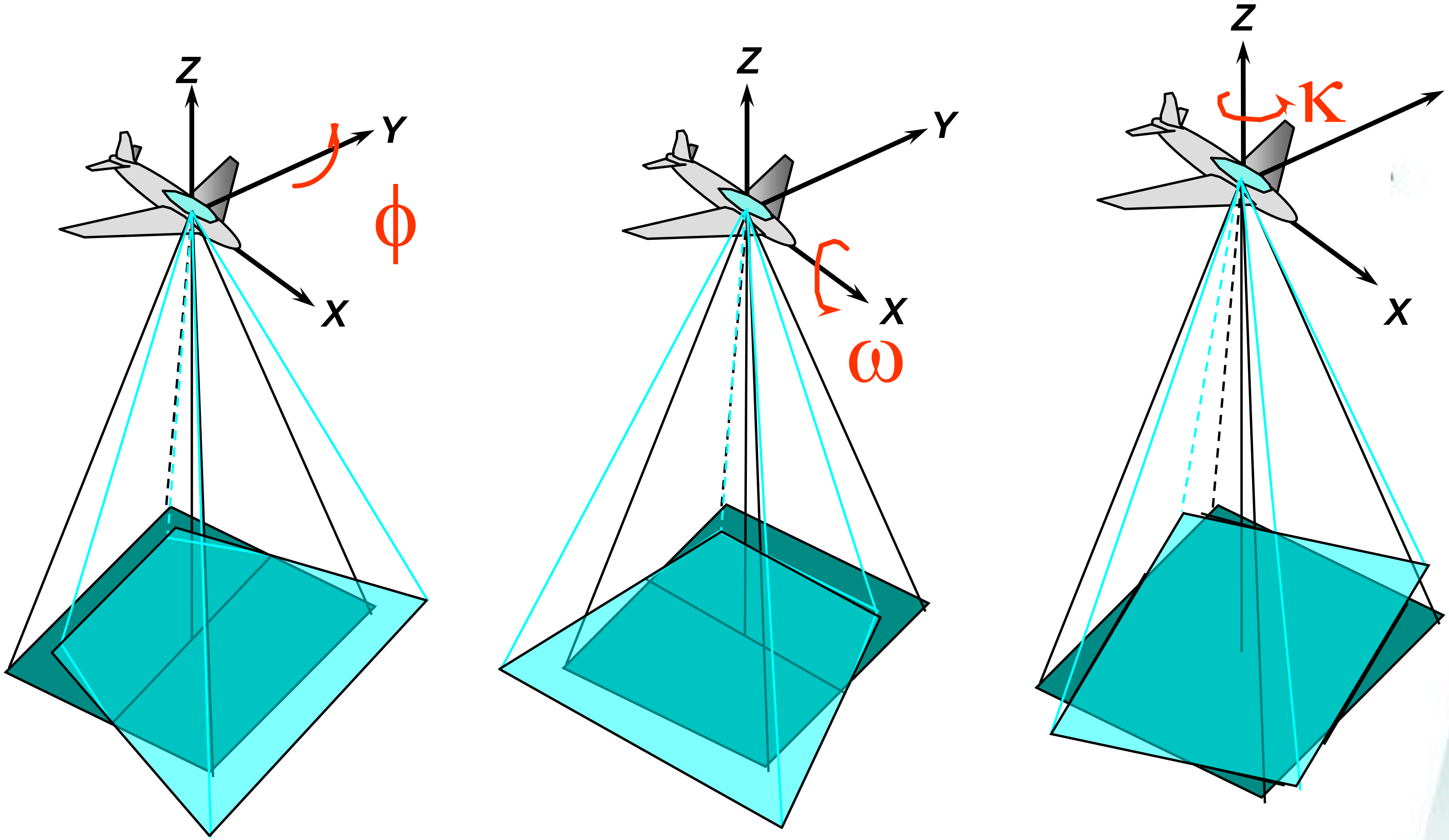
Computes position of Each camera station

- **X,Y and Z (where Z is flying height)**

- **Omega (ω)**
- **Phi (ρ)**
- **Kappa (κ)**

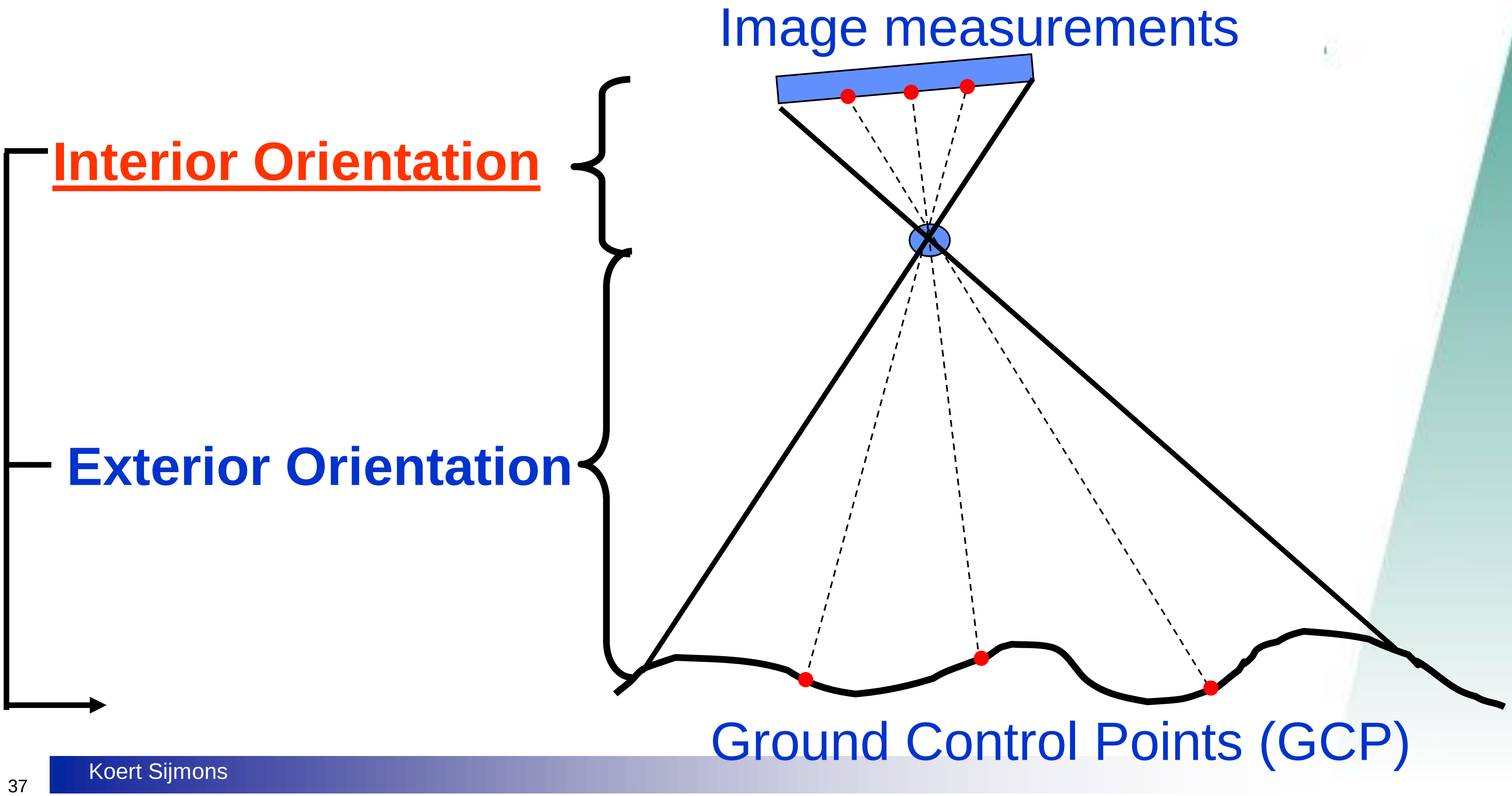
Aerial photographs

κ, ϕ, ω Deformations



Photogrammetric Triangulation

- How do you do it?



Interior Orientation

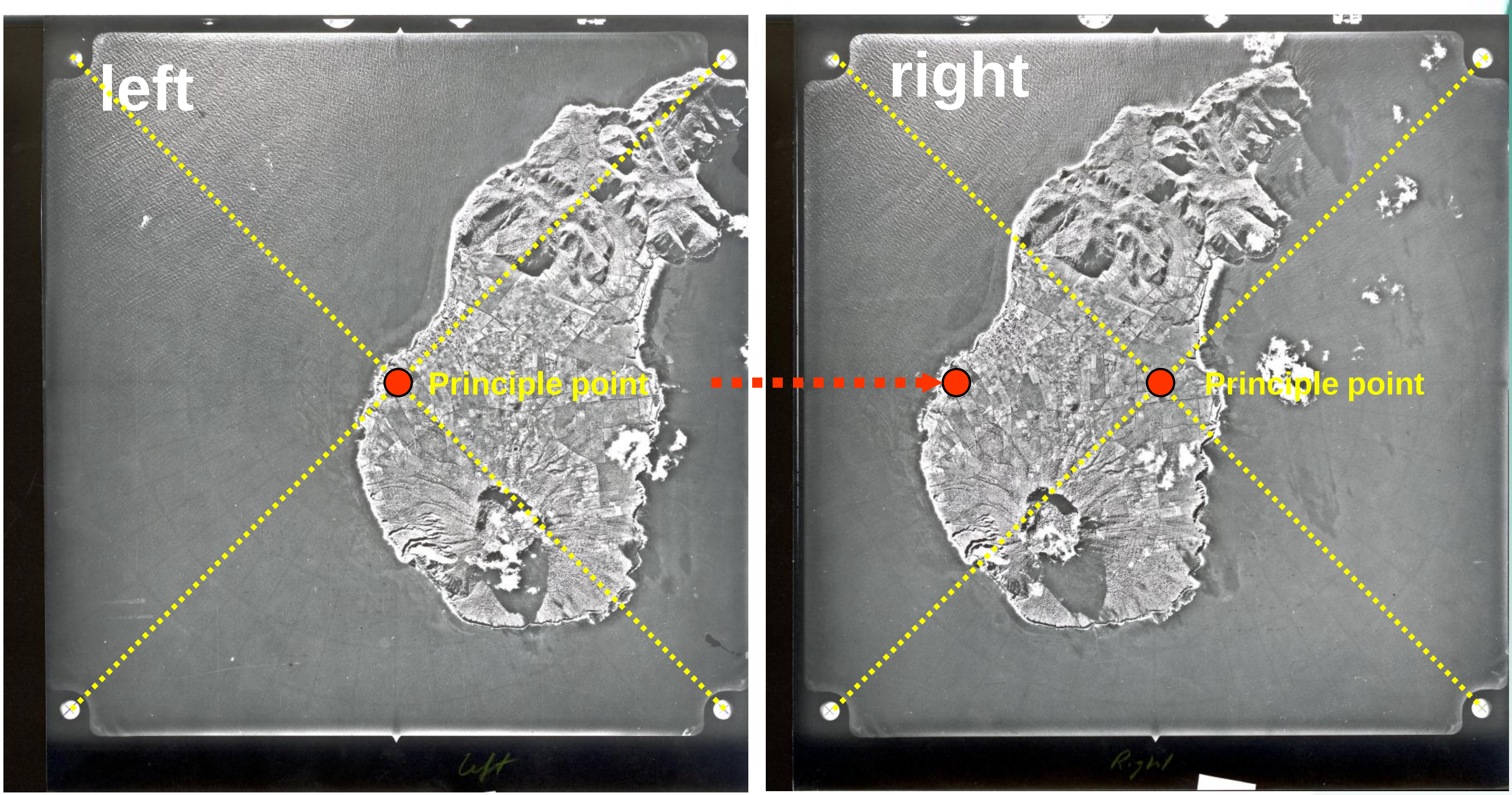
- **Objective: Interior Orientation models the geometry inside the camera**

  - **Lens focal length**
  - **Origin of co-ordinate system (principal point)**
  - **Radial lens distortion**

- **Coordinate systems**

  - **Establish the relationship between positions in the image (pixel) and the corresponding position in the camera (mm.) The coordinates of the fuducial points in the camera are known.**

Aerial photographs en stereo



Interior Orientation: Image used during demonstration

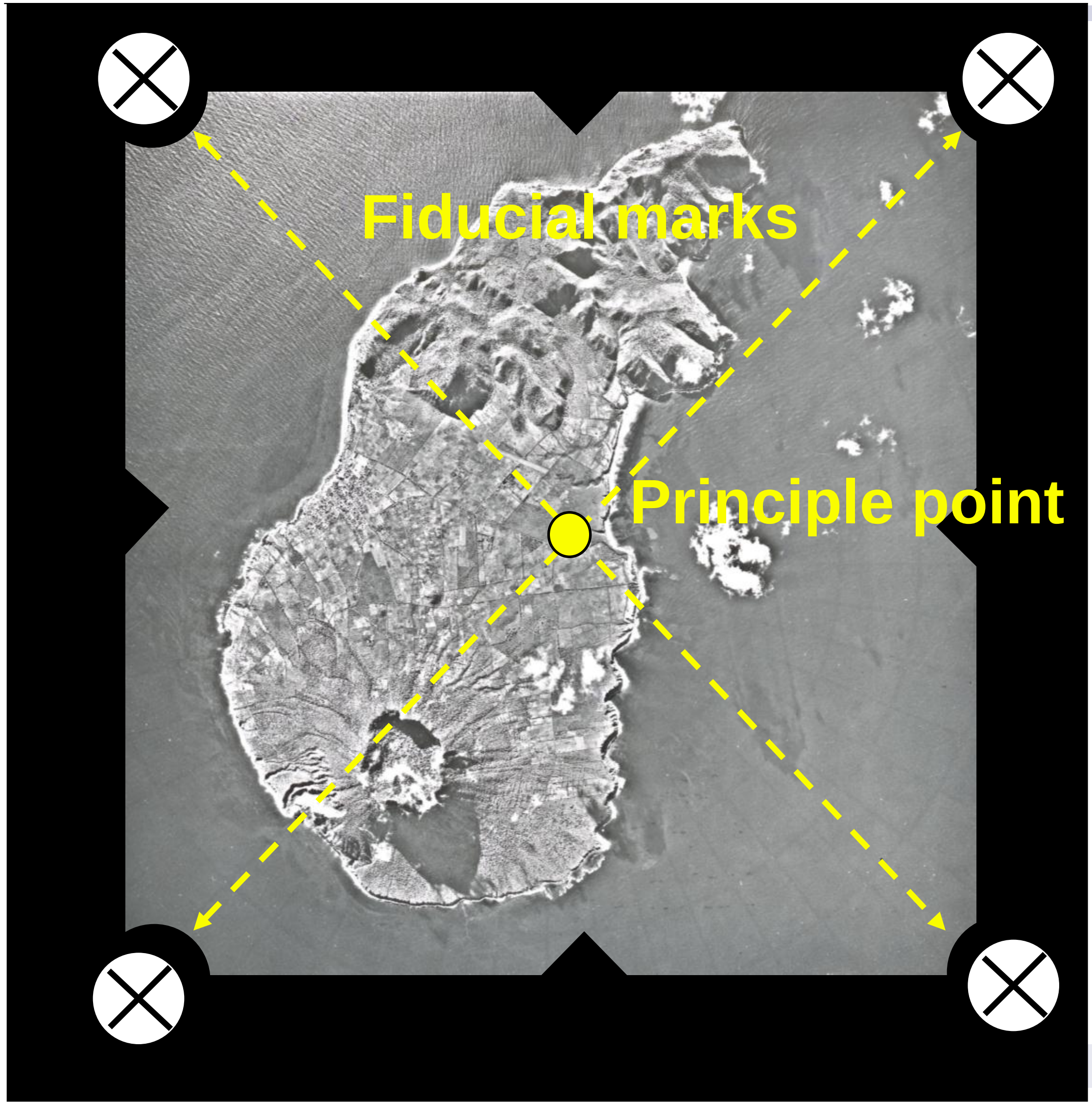


Image details:

Average photo scale:

1:40,500

Scanning resolution:

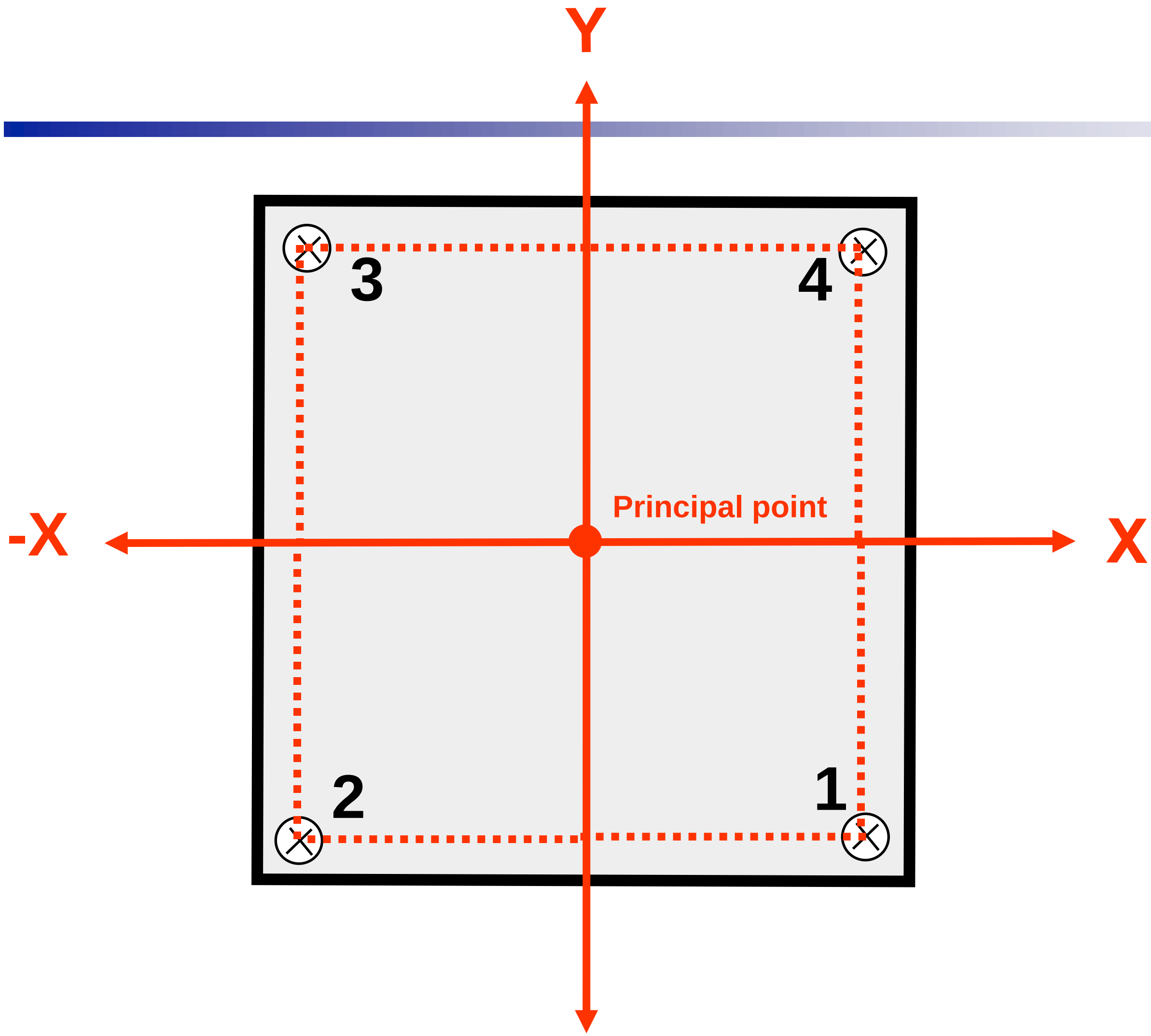
300 DPI

Ground resolution per pixel:

(2.54 / 300)*405 = 3.43 m.

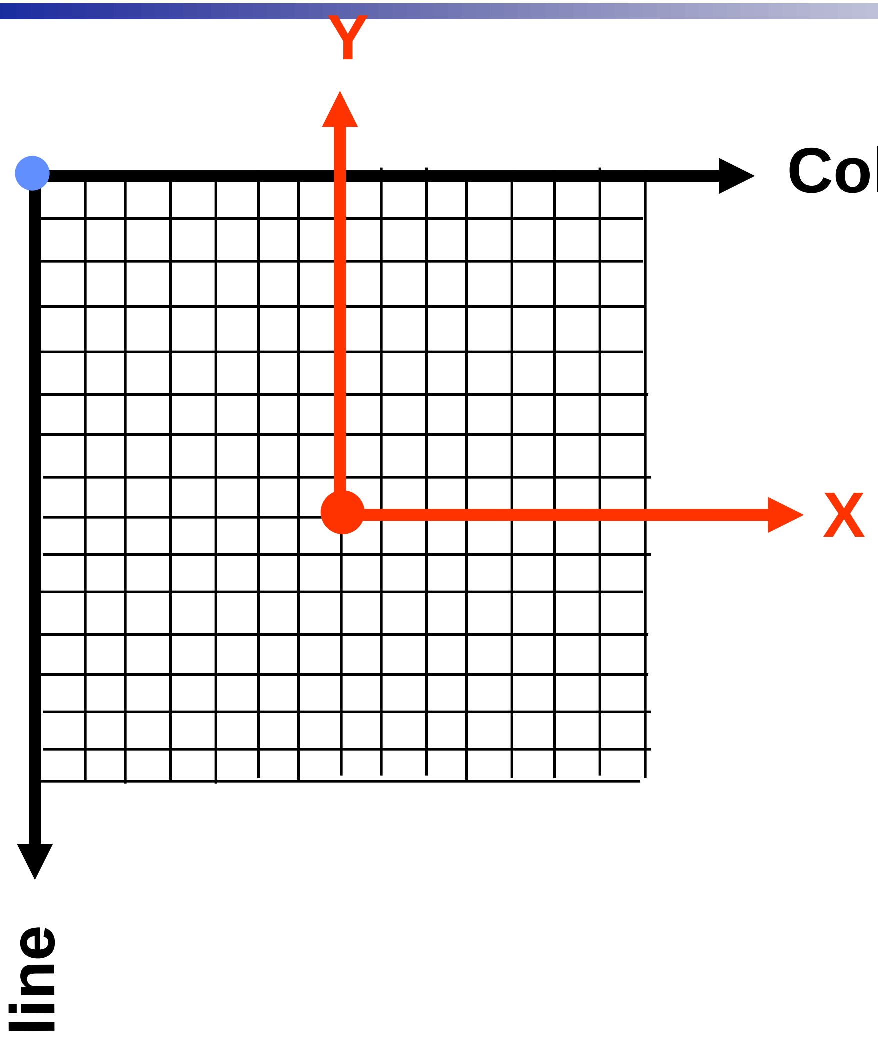
Interior Orientation

- **Film: coordinate position are measured in microns (Image coordinate system)**
- **Digital image: coordinates positions are measured in pixels (Pixel coordinate system)**
- **Using fiducial points a linear relationship can be established between film and image coordinate postions**



X and Y coordenates of the fudicial points

1:	106.004	-106.008
2:	-105.999	-105.998
3:	-106.004	106.005
4:	106.002	106.002



Relation between

Pixel coordinates

(Line,Column)

and

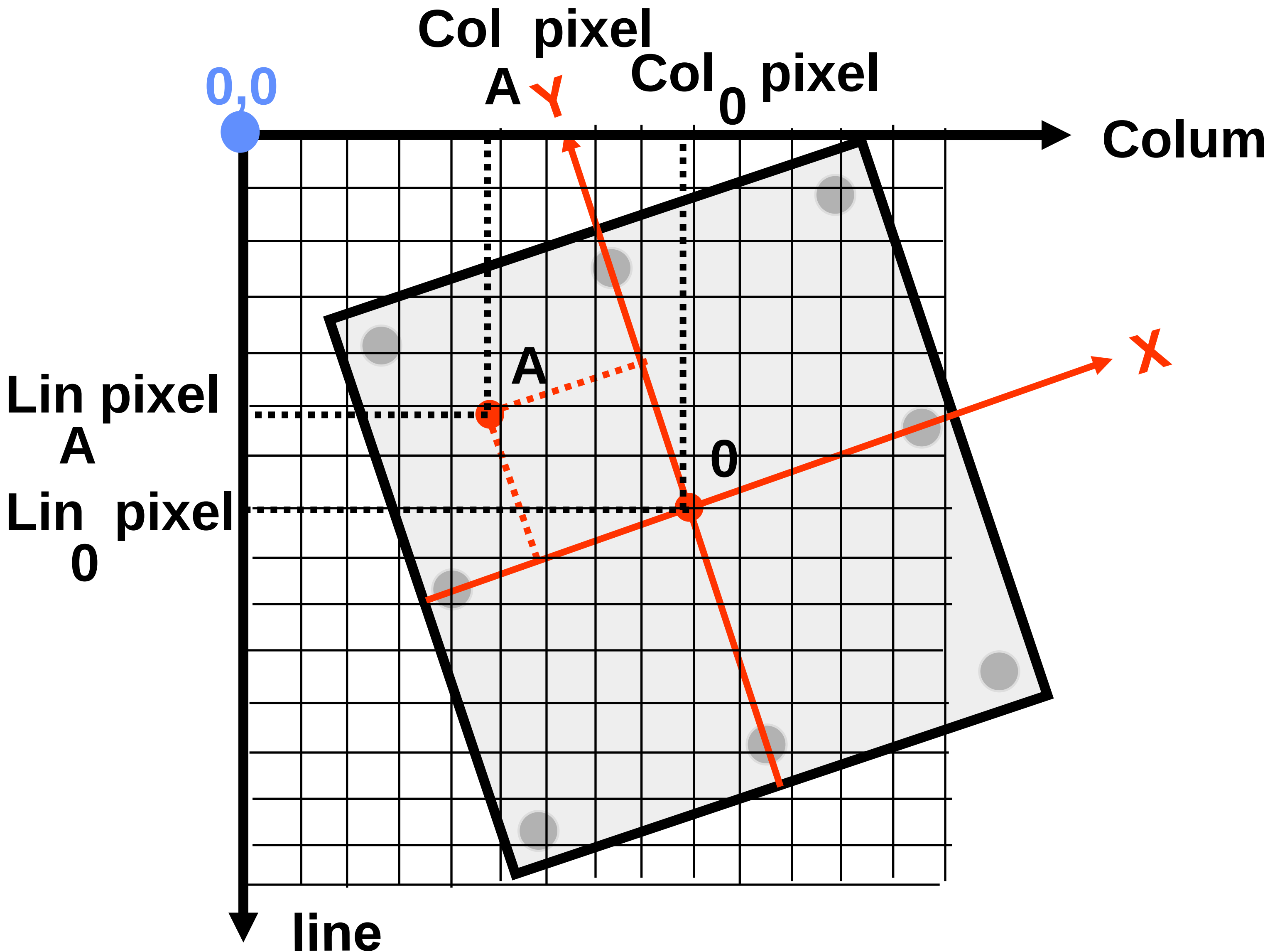
Image coordinates

(in the camera in millimeters)

(x,y)

Image coordinate system (film)

Pixel coordinate system



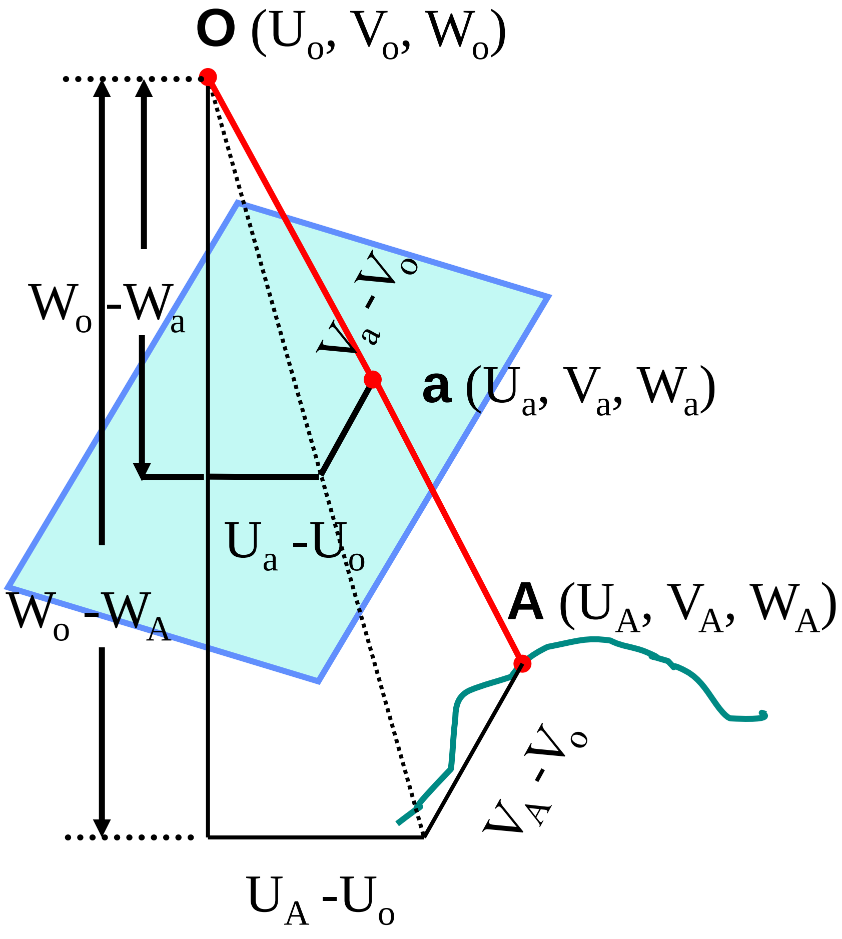
Interior Orientation

- Camera calibration information
  - Obtained from "camera calibration certificate"
  - Calibration elements:
    - Focal Length
    - Fiducial coordinates
    - Principal point location
    - Radial lens distortion

Exterior Orientation

- **Objective: Establishing a relationship between the digital image (pixel) co-ordinate system and the real world (latitude and longitude) co-ordinate system**
- **Ground Control Points**
  - Visually identifiable
  - Preferably on multiple images
  - Larger image blocks need less control per image
  - Need to be well distributed in X,Y and Z
  - Ground control types:
    - Full (X,Y,Z)
    - Horizontal (X,Y)
    - Vertical (Z)

colinearity condition



O: Projection centre

A: Point on the ground

a: Image of A on the photograph

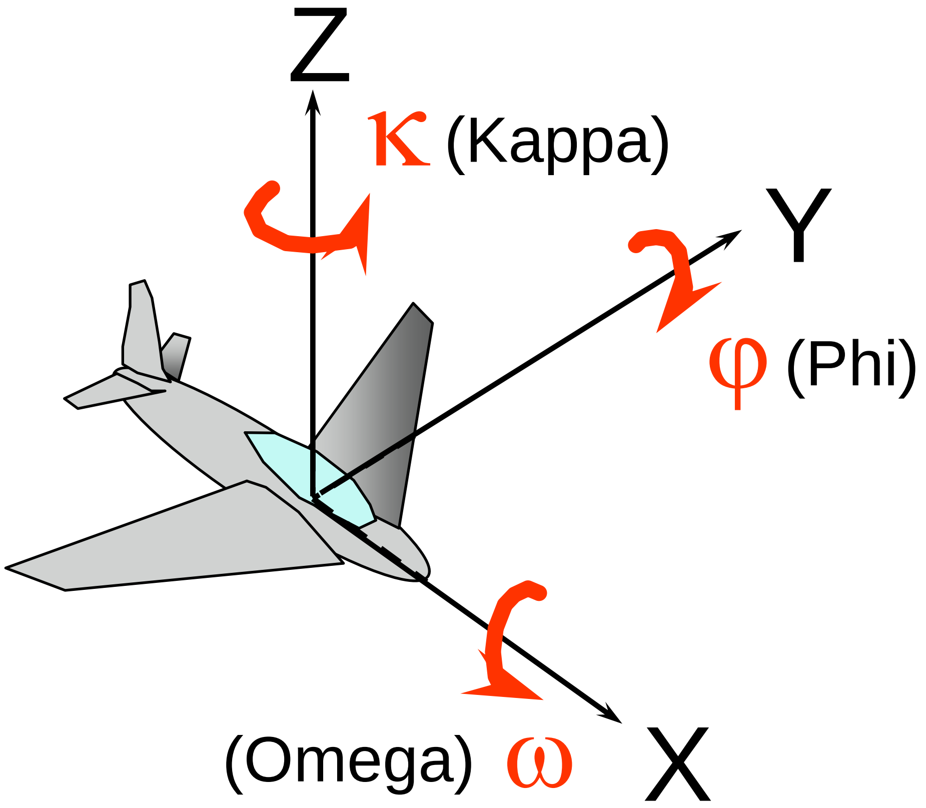
from similar triangles:

$$\frac{U_A - U_o}{U_a - U_o} = \frac{V_A - V_o}{V_a - V_o} = \frac{W_A - W_o}{W_a - W_o} = s_a$$

or :

$$\begin{bmatrix} U_A - U_o \\ V_A - V_o \\ W_A - W_o \end{bmatrix} = s_a * \begin{bmatrix} U_a - U_o \\ V_a - V_o \\ W_a - W_o \end{bmatrix}$$

angles κ, φ, ω



What do these letters mean?

$$x = -c \cdot \frac{r_{11} \cdot (U - U_o) + r_{12} \cdot (V - V_o) + r_{13} \cdot (W - W_o)}{r_{31} \cdot (U - U_o) + r_{32} \cdot (V - V_o) + r_{33} \cdot (W - W_o)} + x_{PP}$$

$$y = -c \cdot \frac{r_{21} \cdot (U - U_o) + r_{22} \cdot (V - V_o) + r_{23} \cdot (W - W_o)}{r_{31} \cdot (U - U_o) + r_{32} \cdot (V - V_o) + r_{33} \cdot (W - W_o)} + y_{PP}$$

Position of a point in the image: x, y

Position of the corresponding terrain point: U, V, W

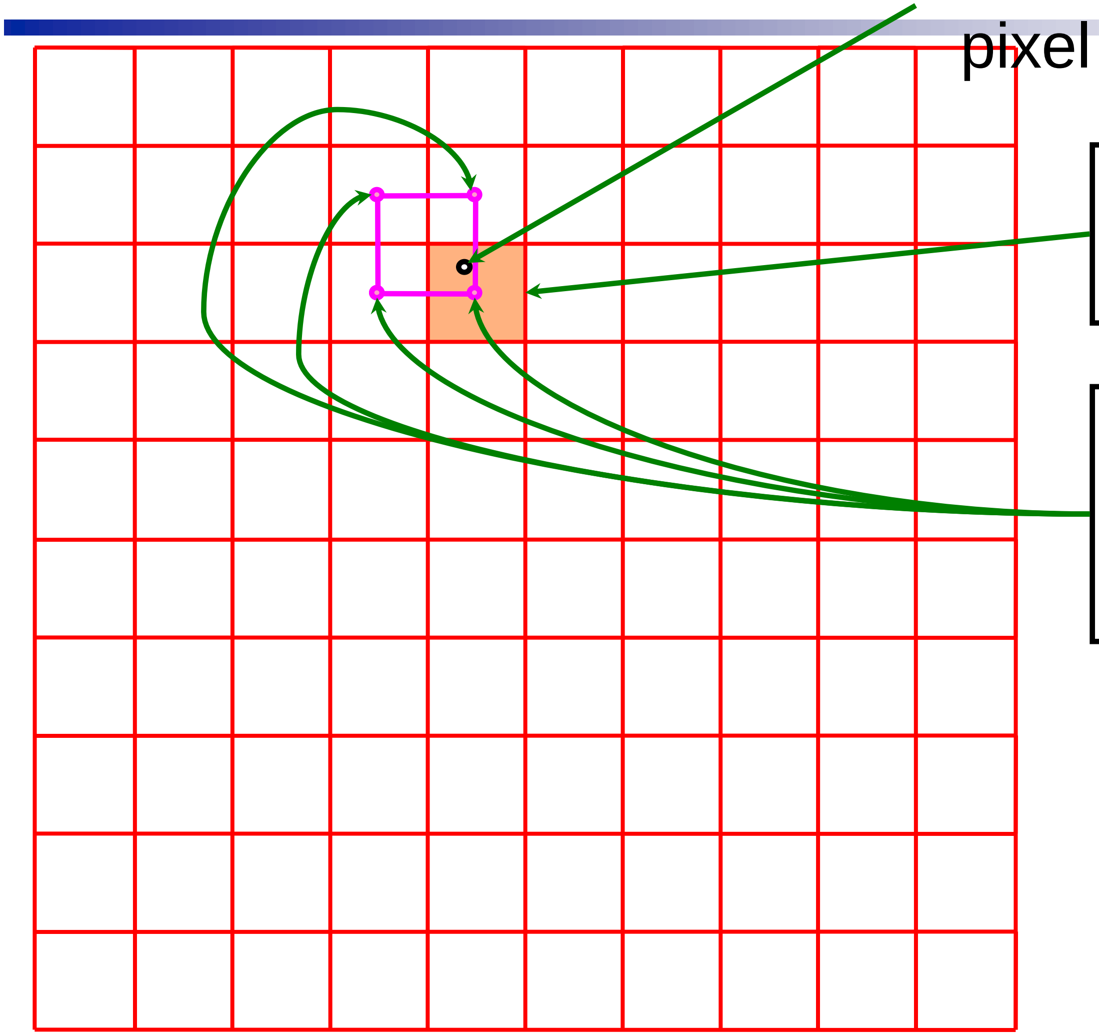
Known after interior orientation: x_{PP}, y_{PP} , c

From Exterior orientation: U_o, V_o , W_o,

r_{11}, r_{12}, r_{13}, r_{21}, r_{22}, r_{23}, r_{31}, r_{32}, r_{33} (computed from of κ , φ , ω)

For each point in the terrain its position in the image can be computed from these two equations. (Different for the left and the right image.)

Resampling one pixel

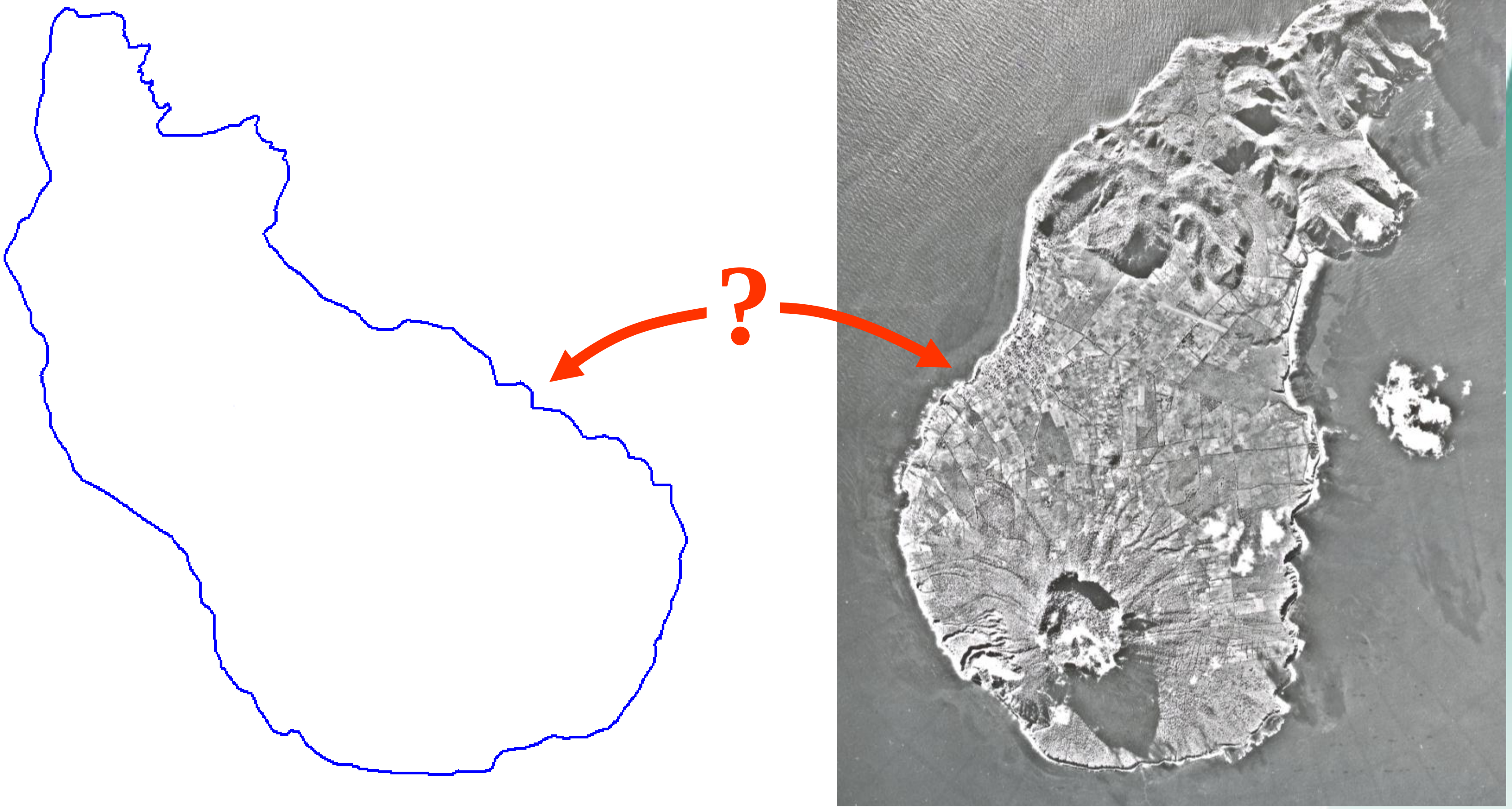


Center of the orthophoto-pixel in the original image

“Nearest neighbour”: the value of this pixel

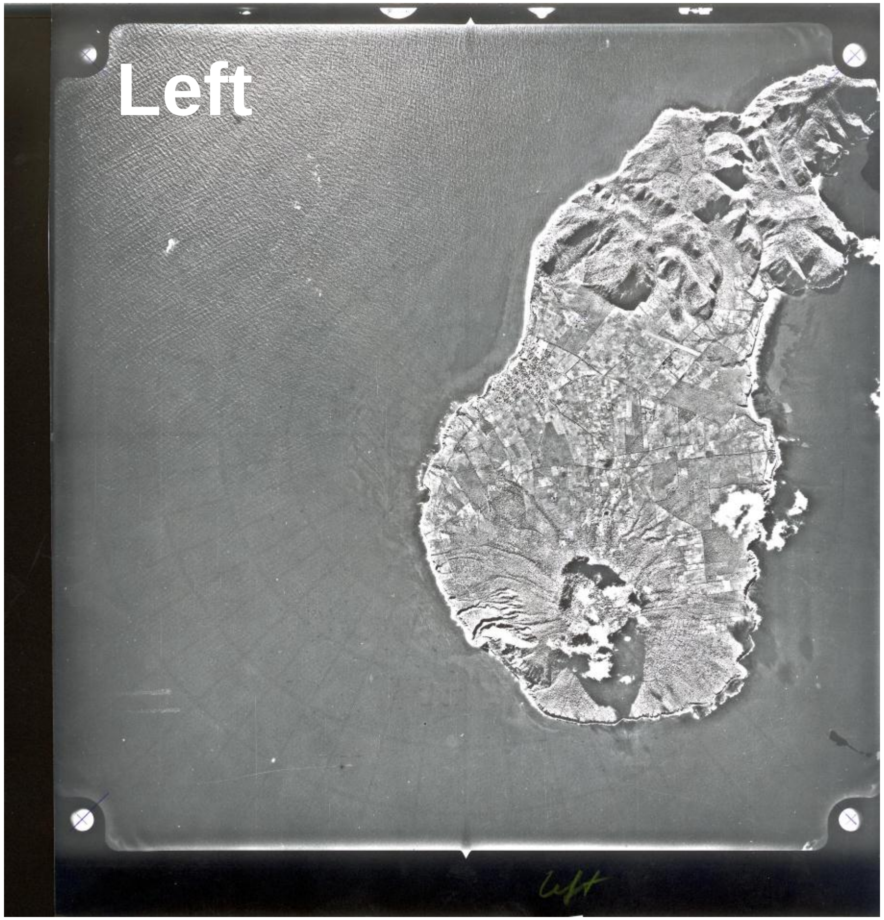
“Bilinear”: interpolated between these 4 pixelcenters

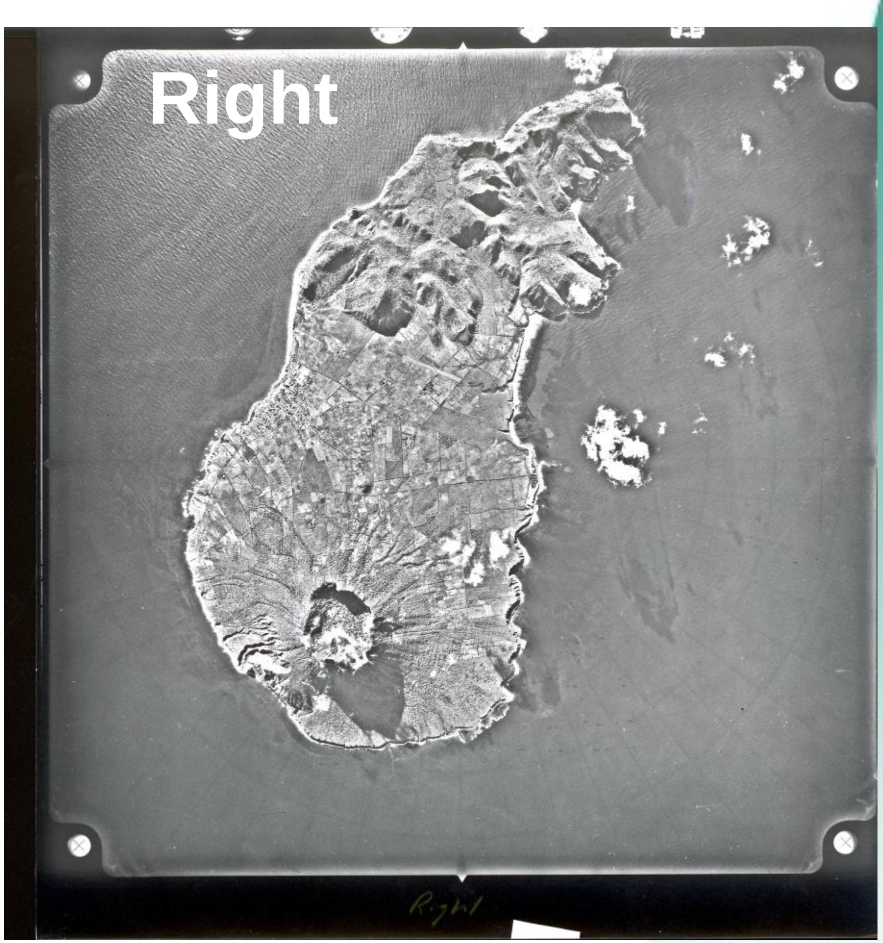
Example St Eustatius: How to accurately transfer interpretation from photo to map!!!



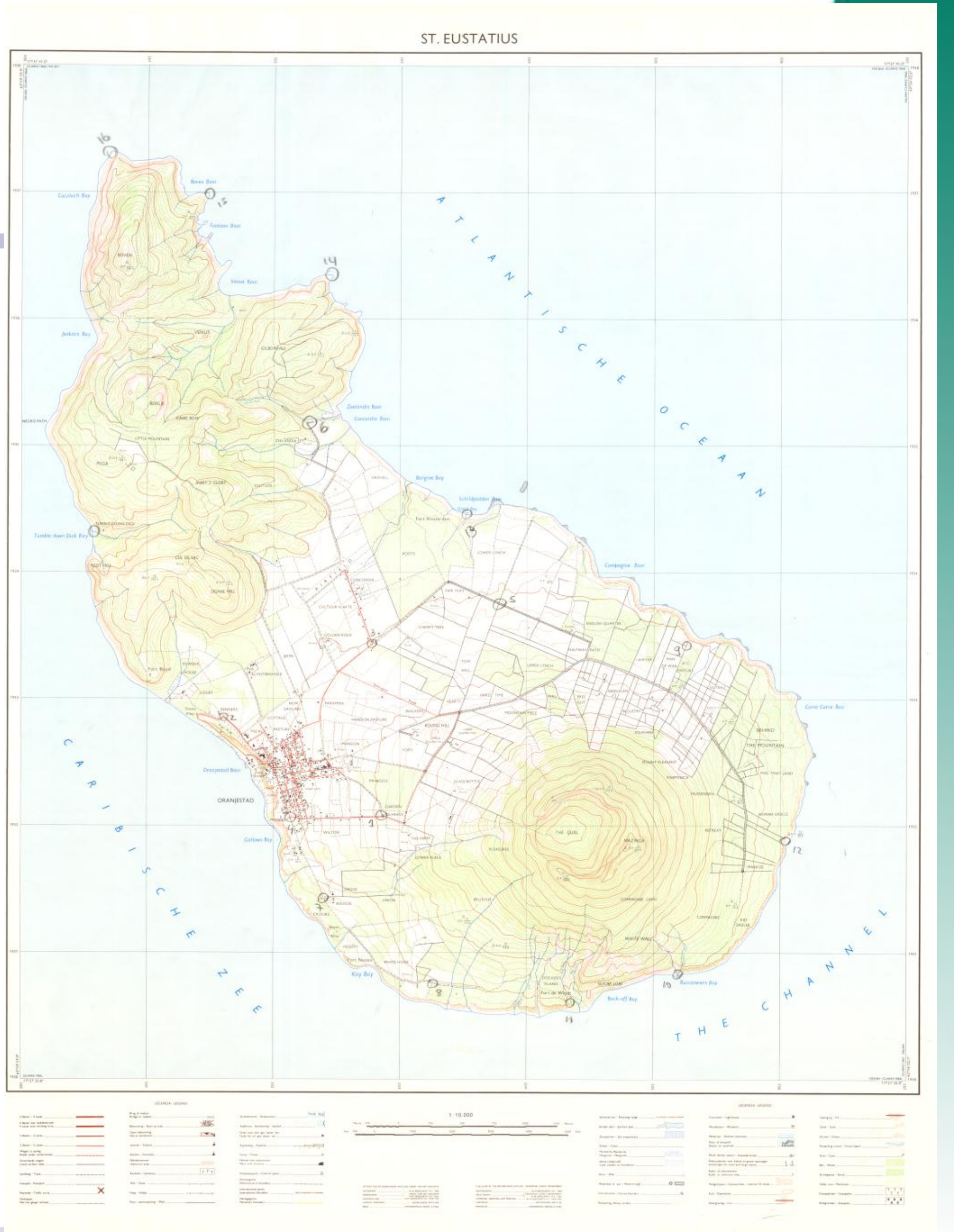
Shoreline from topographical map **Aerial photo**

Available:
2 digital stereo Aerial Photos at scale 1:40,000 of the Island of Sint Eustasius (Caribbean Sea)





Available: Topographic map at scale:1:10,000 of St. Eustasius



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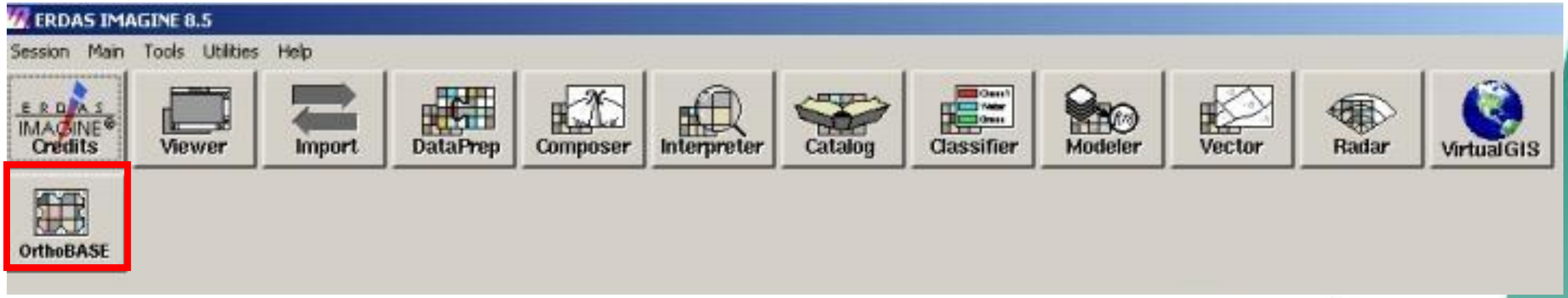
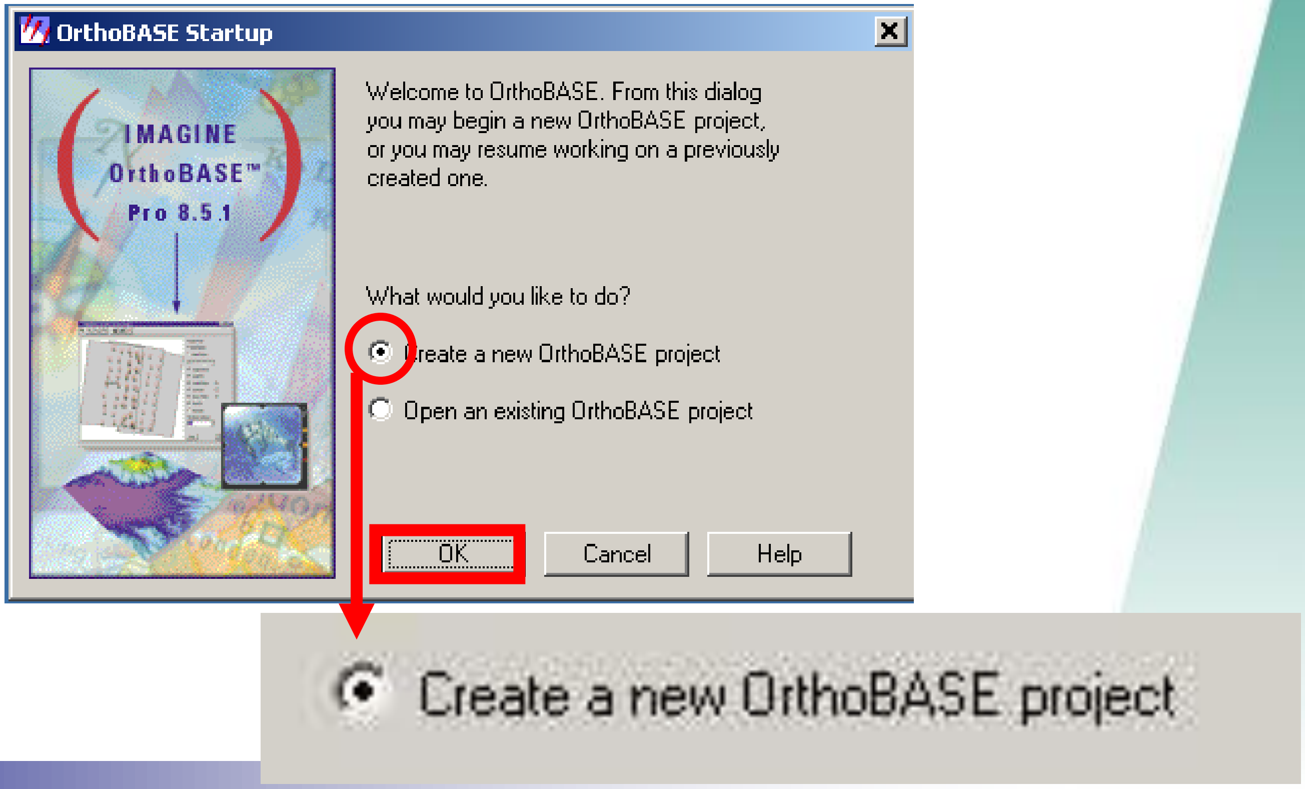




Welcome to OrthoBASE. From this dialog you may begin a new OrthoBASE project, or you may resume working on a previously created one.

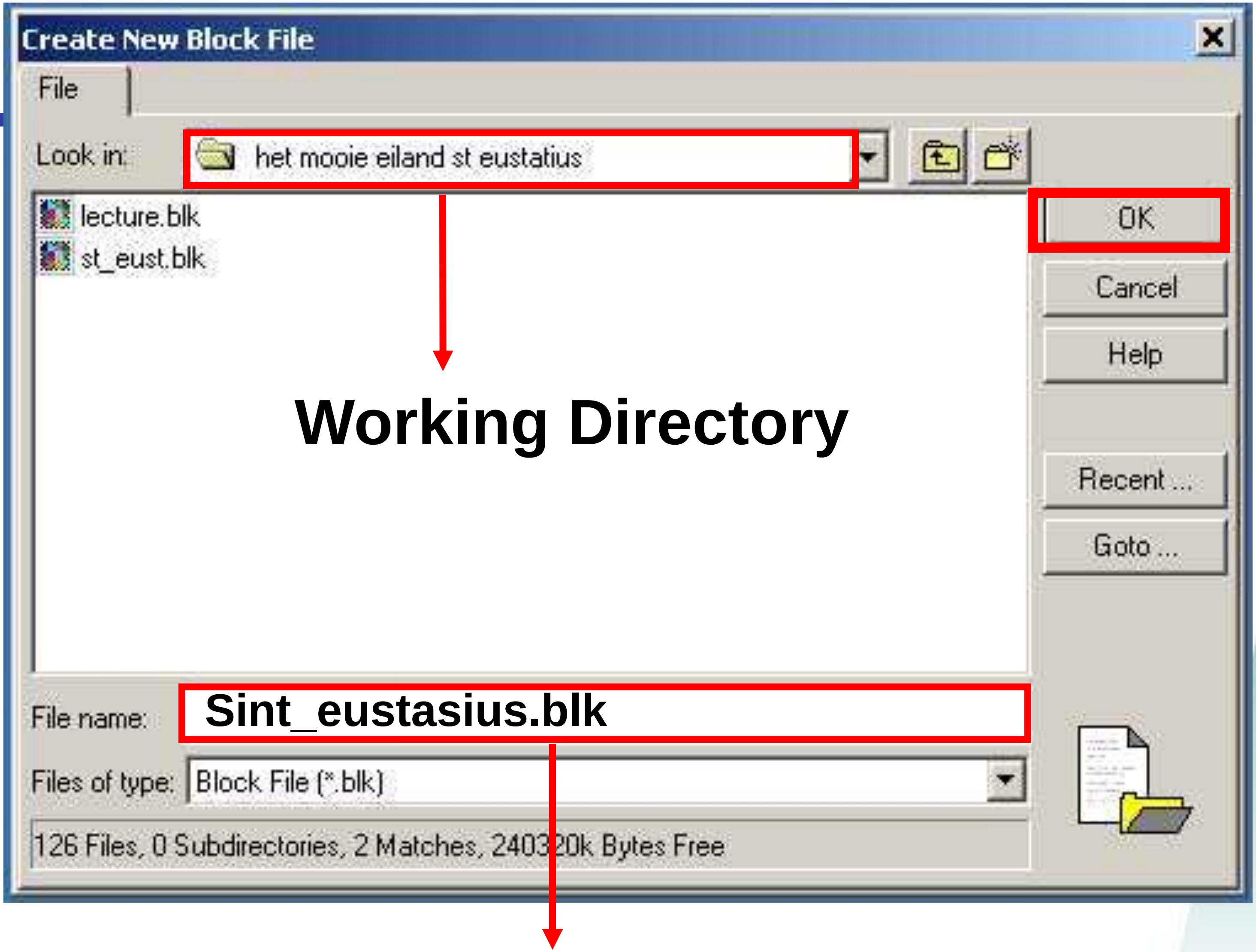
What would you like to do?

● Create a new OrthoBASE project

○ Open an existing OrthoBASE project

● Create a new OrthoBASE project

Create New Block File



Look in: het mooie eiland st eustatius

lecture.blk
st_eust.blk

File name: Sint_eustasius.blk

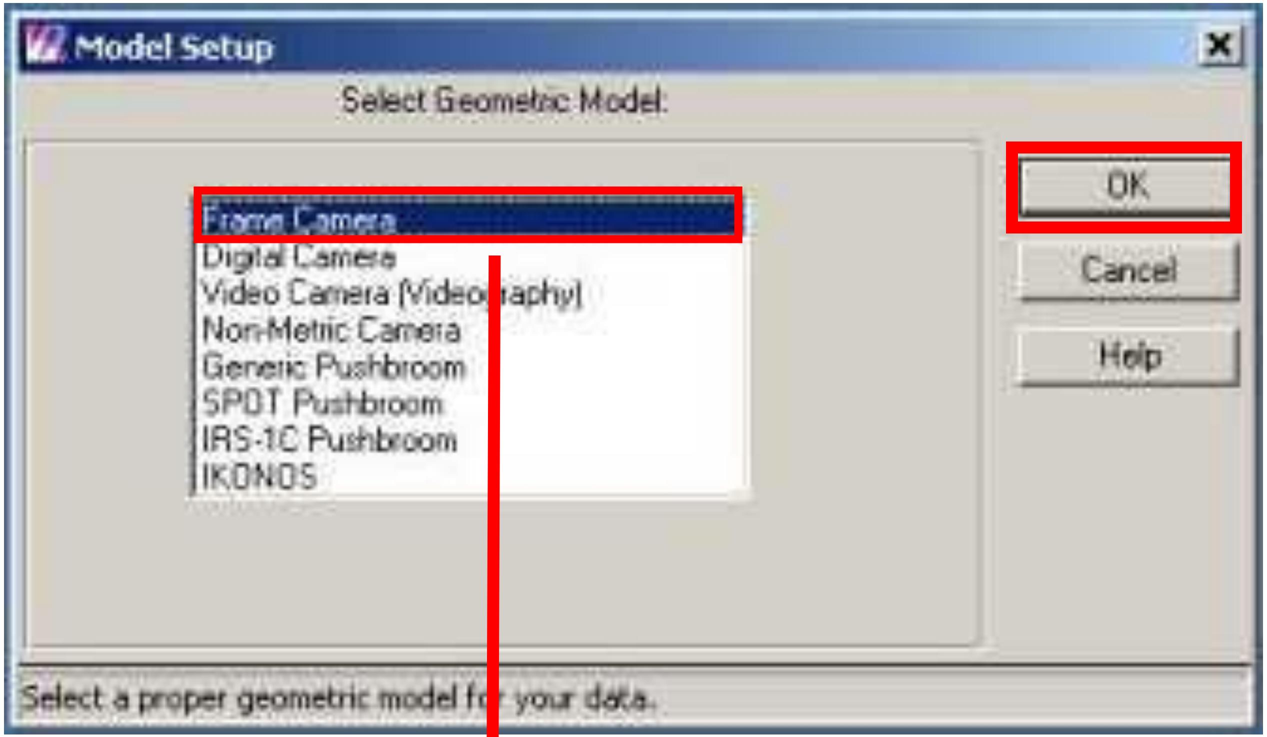
Files of type: Block File (*.blk)

126 Files, 0 Subdirectories, 2 Matches, 240320k Bytes Free

Working Directory

Type: Block File name

Setup of Geometric Model



Model Setup

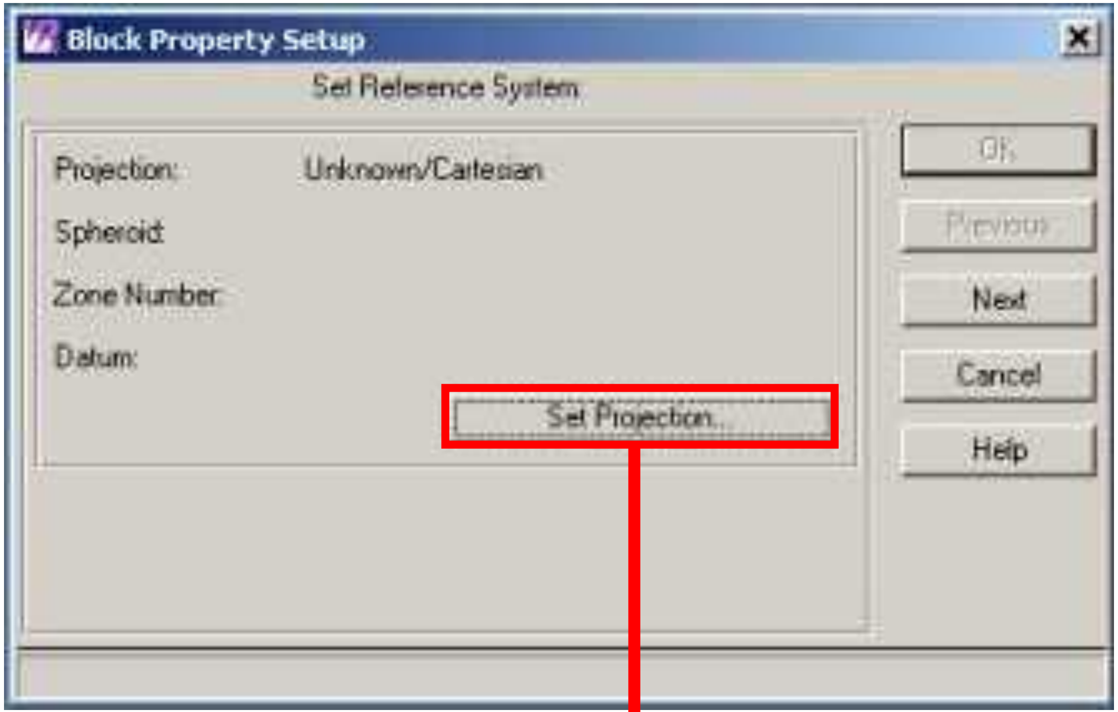
Select Geometric Model:

- Frame Camera
- Digital Camera
- Video Camera (Videography)
- Non-Metric Camera
- Generic Pushbroom
- SPOT Pushbroom
- IRS-1C Pushbroom
- IKONOS

Select a proper geometric model for your data.

Frame Camera

Select Projection



Block Property Setup

Set Reference System

Projection: Unknown/Cartesian

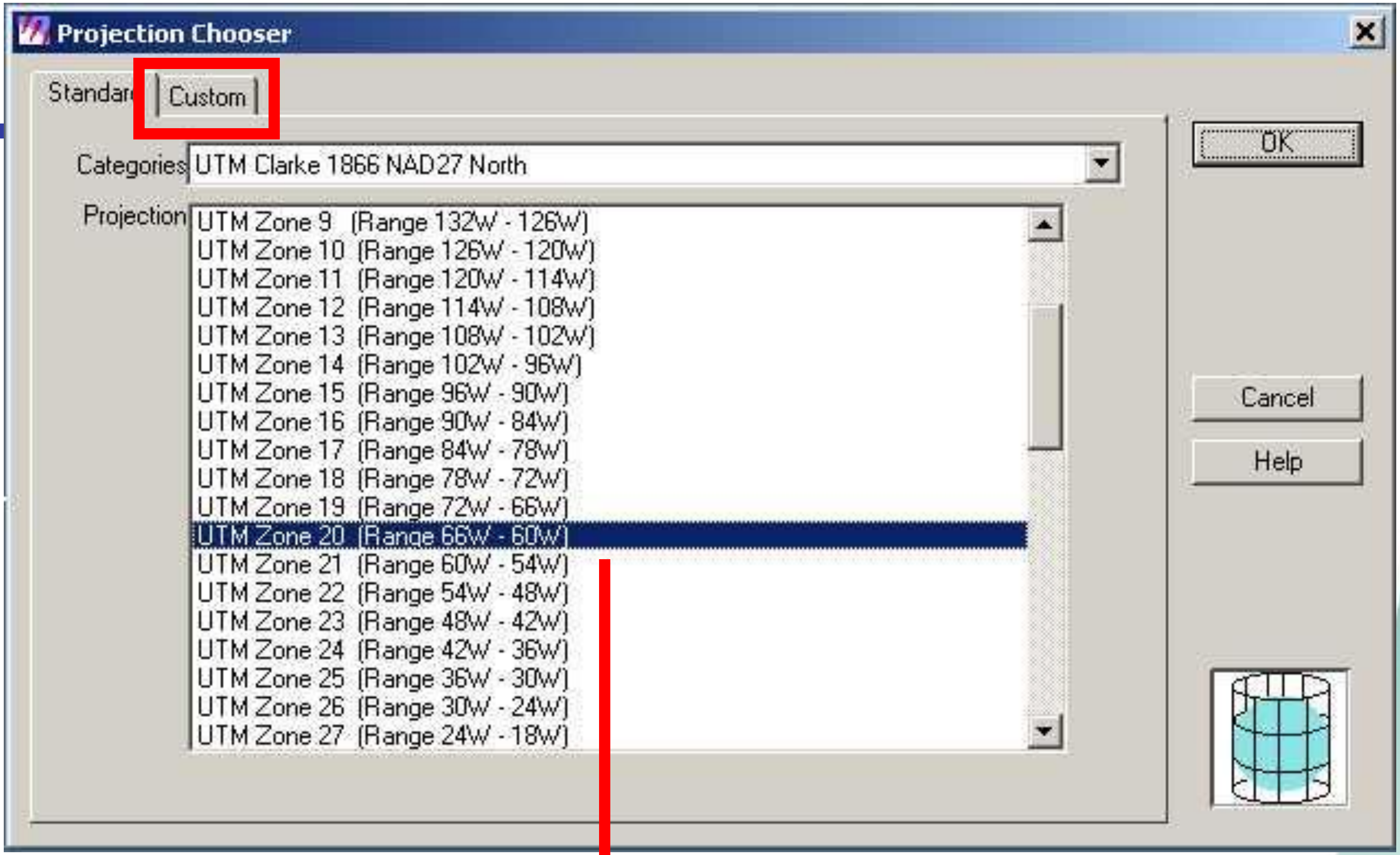
Spheroid:

Zone Number:

Datum:

Set Projection

Select Projection

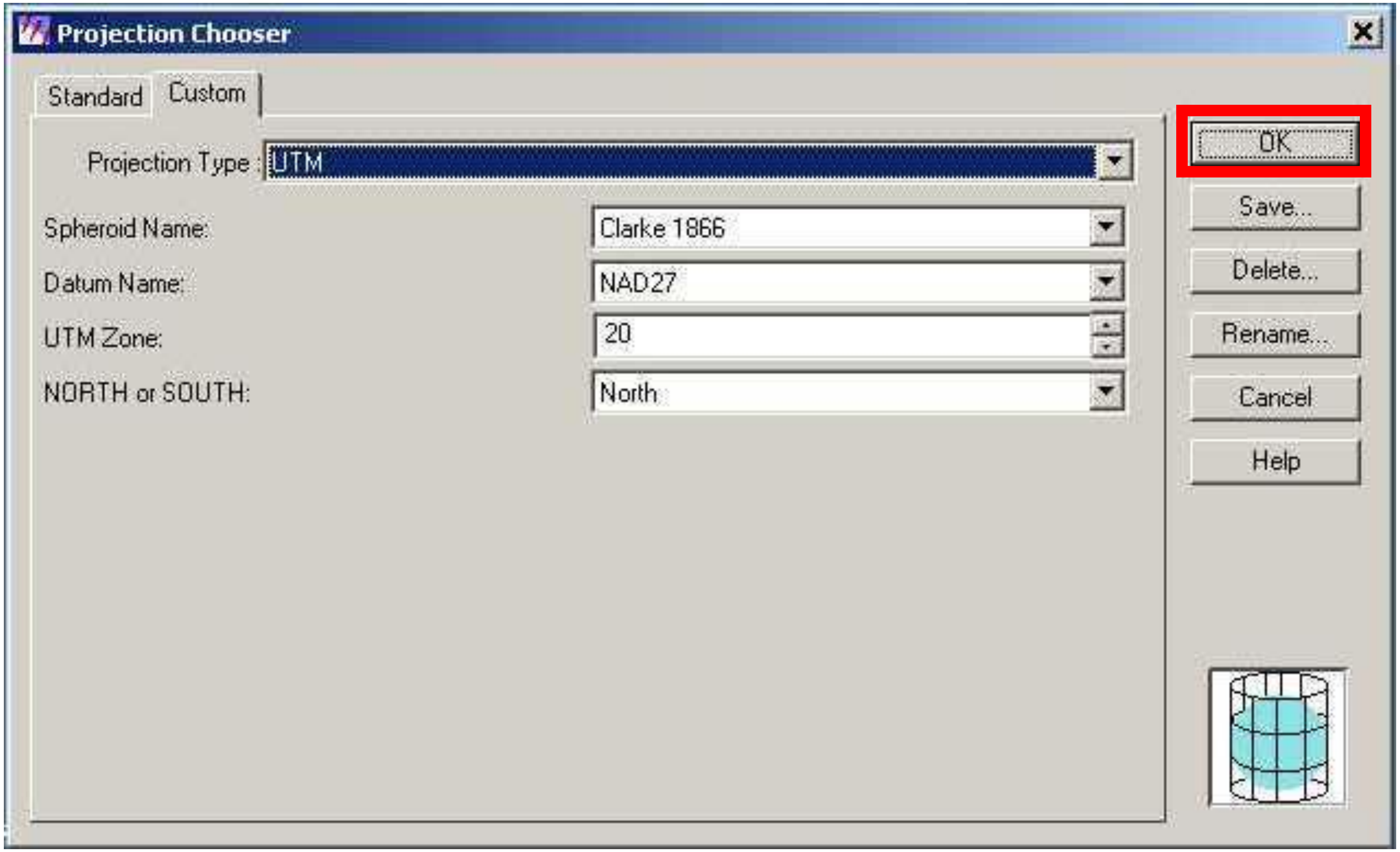


Categories: UTM Clarke 1866 NAD27 North

Projection:
- UTM Zone 9 (Range 132W - 126W)
- UTM Zone 10 (Range 126W - 120W)
- UTM Zone 11 (Range 120W - 114W)
- UTM Zone 12 (Range 114W - 108W)
- UTM Zone 13 (Range 108W - 102W)
- UTM Zone 14 (Range 102W - 96W)
- UTM Zone 15 (Range 96W - 90W)
- UTM Zone 16 (Range 90W - 84W)
- UTM Zone 17 (Range 84W - 78W)
- UTM Zone 18 (Range 78W - 72W)
- UTM Zone 19 (Range 72W - 66W)
- UTM Zone 20 (Range 66W - 60W)
- UTM Zone 21 (Range 60W - 54W)
- UTM Zone 22 (Range 54W - 48W)
- UTM Zone 23 (Range 48W - 42W)
- UTM Zone 24 (Range 42W - 36W)
- UTM Zone 25 (Range 36W - 30W)
- UTM Zone 26 (Range 30W - 24W)
- UTM Zone 27 (Range 24W - 18W)

UTM Zone 20 (Range 66W-60W)

Select Spheroid Name



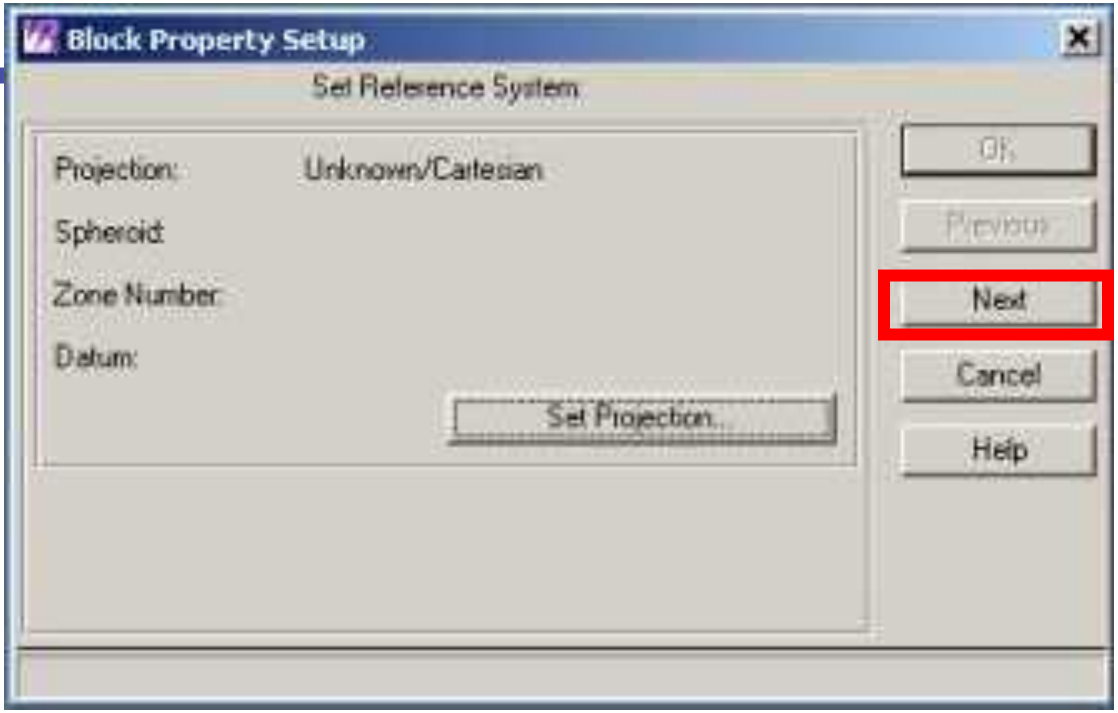
Projection Type : UTM

Spheroid Name: Clarke 1866

Datum Name: NAD27

UTM Zone: 20

NORTH or SOUTH: North



Block Property Setup

Set Reference System

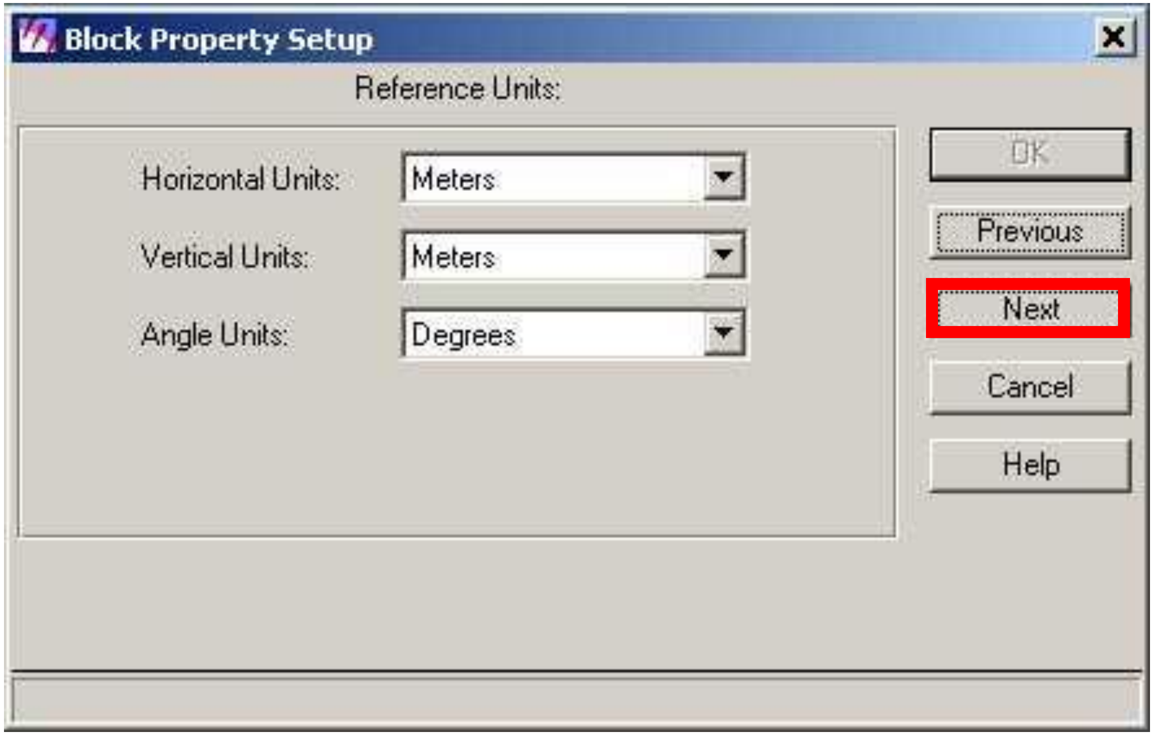
Projection: Unknown/Cartesian

Spheroid:

Zone Number:

Datum:

Set Horizontal/Vertical Units in: Meters



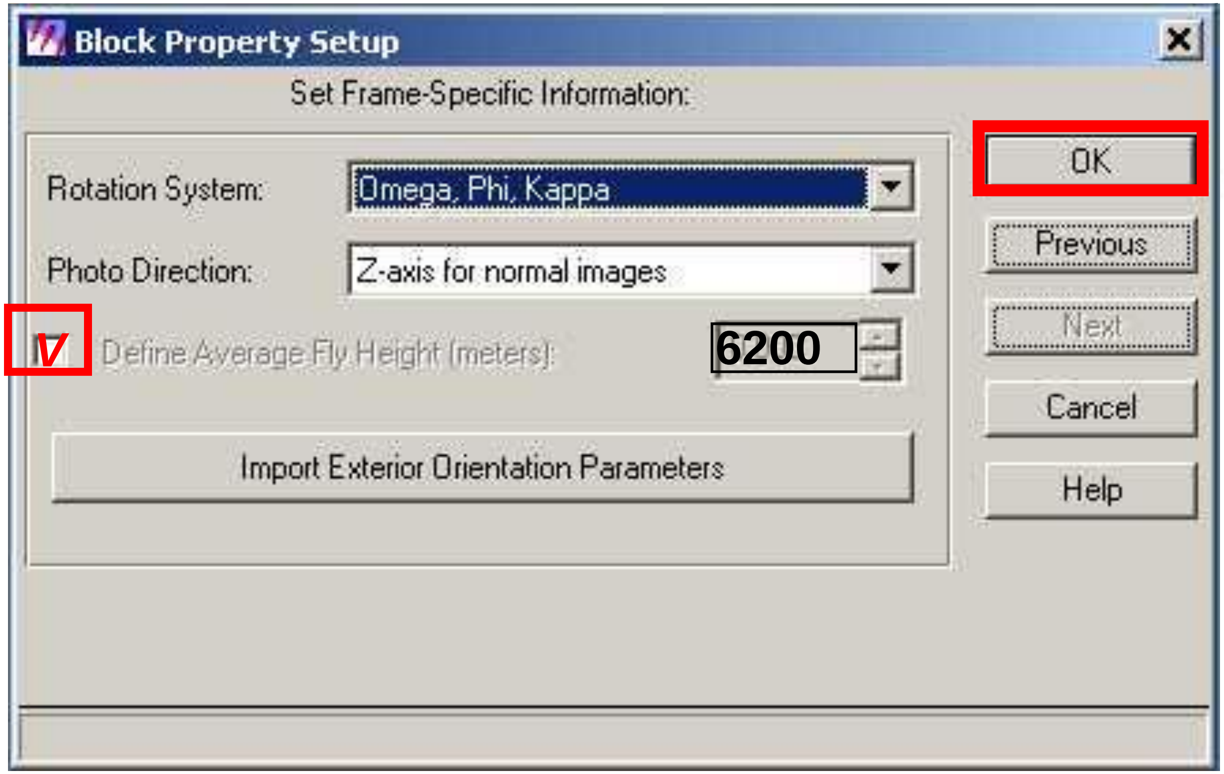
Reference Units:

Horizontal Units: Meters

Vertical Units: Meters

Angle Units: Degrees

Set Fly Height in meters



Block Property Setup

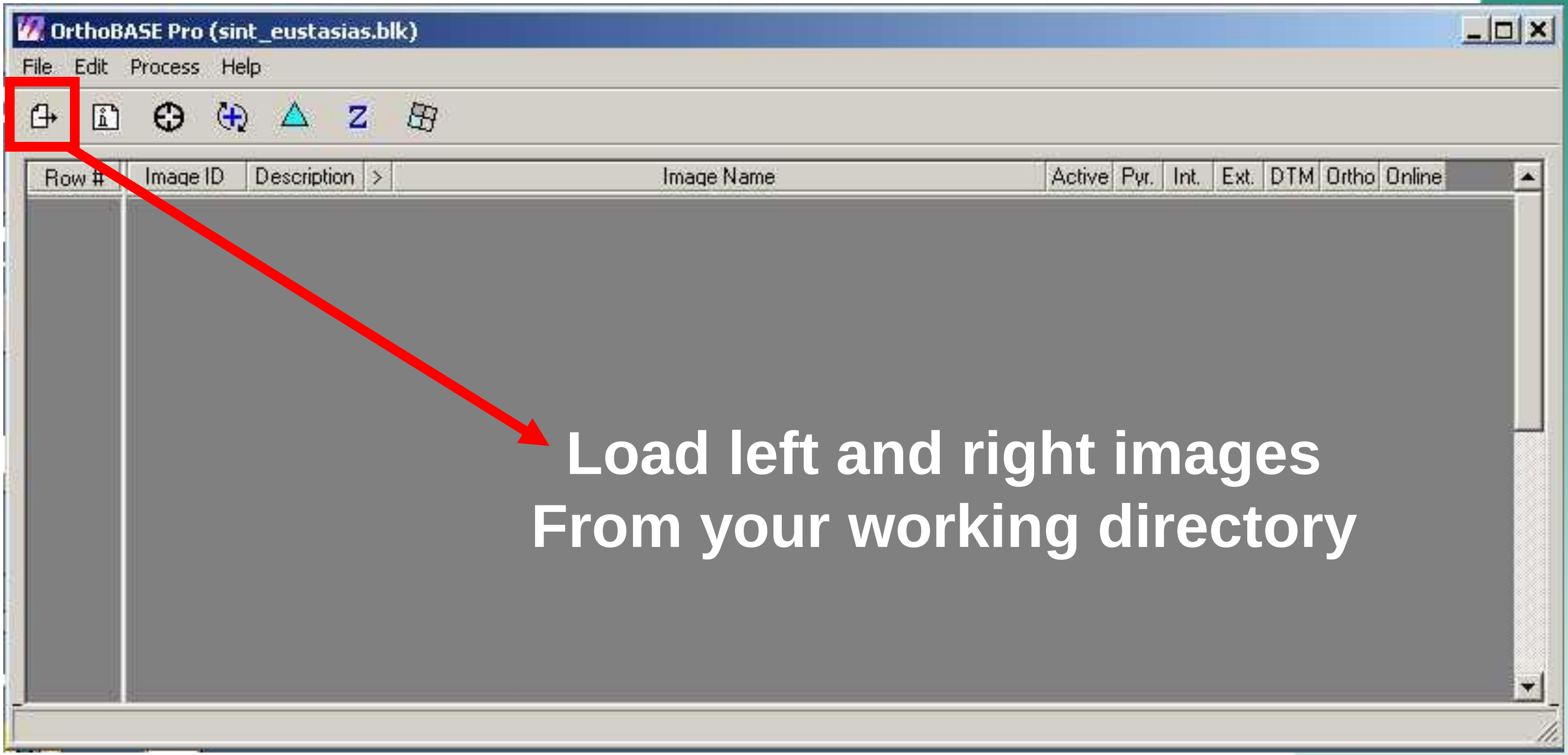
Set Frame-Specific Information:

Rotation System: Omega, Phi, Kappa

Photo Direction: Z-axis for normal images

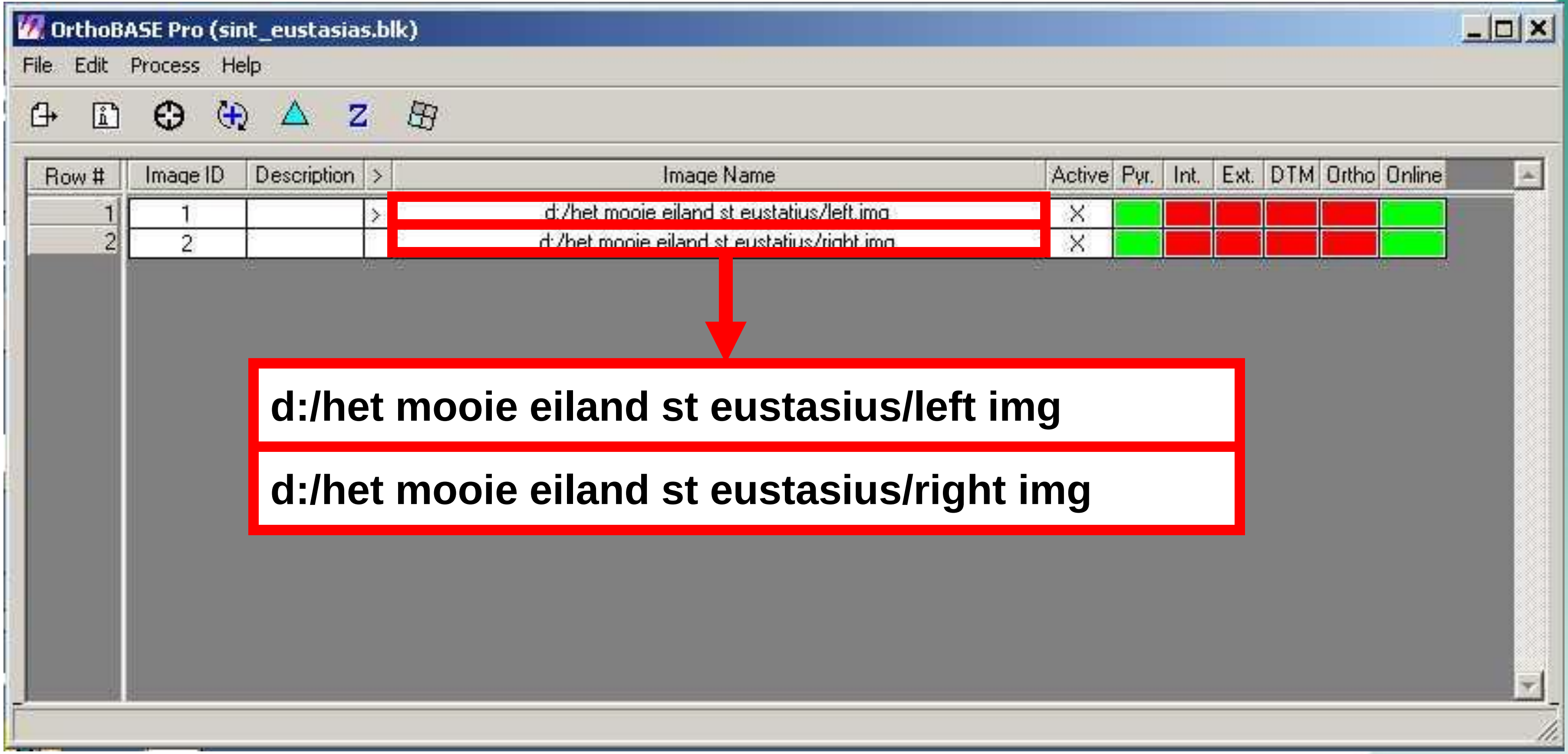
☑ Define Average Fly Height (meters): 6200

Loading images



Load left and right images
From your working directory

Loading Left and Right image



Row #	Image ID	Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1		>	d:/het mooie eiland st eustatius/left.img	X	🟩	🟥	🟥	🟥	🟥	🟩
2	2			d:/het mooie eiland st eustatius/right.img	X	🟩	🟥	🟥	🟥	🟥	🟩

d:/het mooie eiland st eustasius/left img

d:/het mooie eiland st eustasius/right img

Set up for Interior Orientation

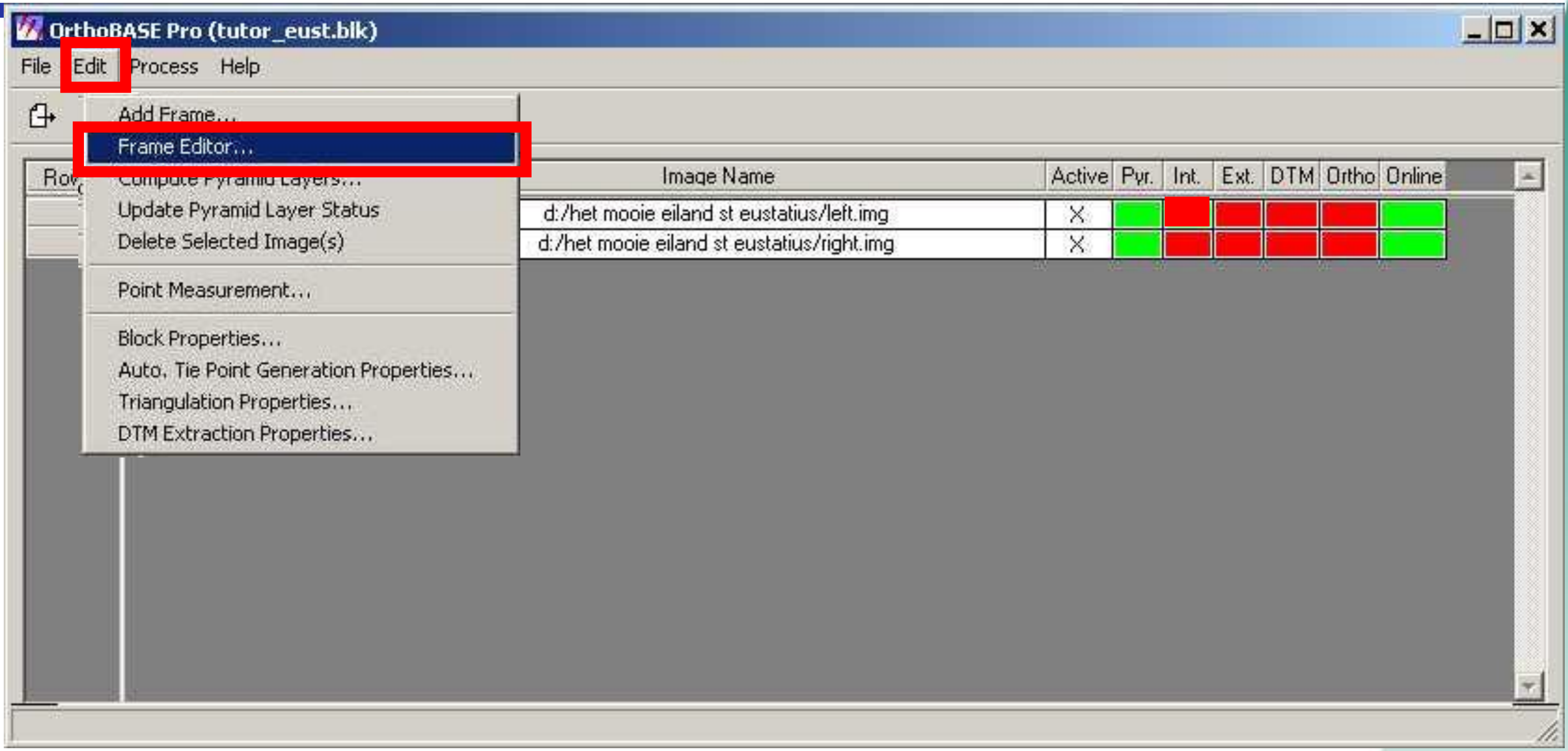
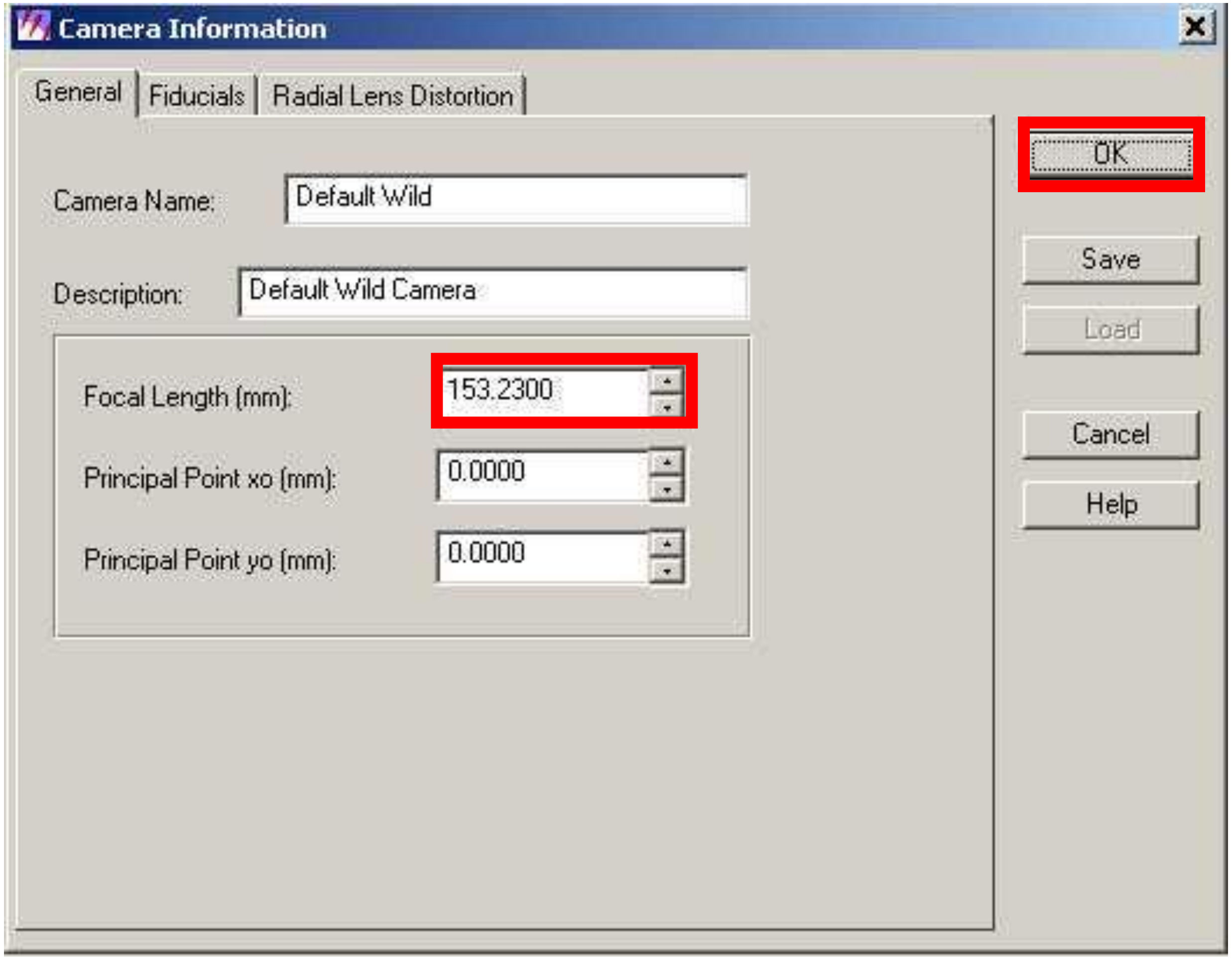

OrthoBASE Pro (tutor_eust.blk)
File
Edit
Process
Help
Add Frame...
Frame Editor...
Compute Pyramid Layers...
Update Pyramid Layer Status
Delete Selected Image(s)
Point Measurement...
Block Properties...
Auto. Tie Point Generation Properties...
Triangulation Properties...
DTM Extraction Properties...
Row
Image Name
Active
Pyr.
Int.
Ext.
DTM
Ortho
Online

Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
d:/het mooie eiland st eustatius/left.img	X	🟩	🟥	🟥	🟥	🟥	🟩
d:/het mooie eiland st eustatius/right.img	X	🟩	🟥	🟥	🟥	🟥	🟩

Set Focal Length



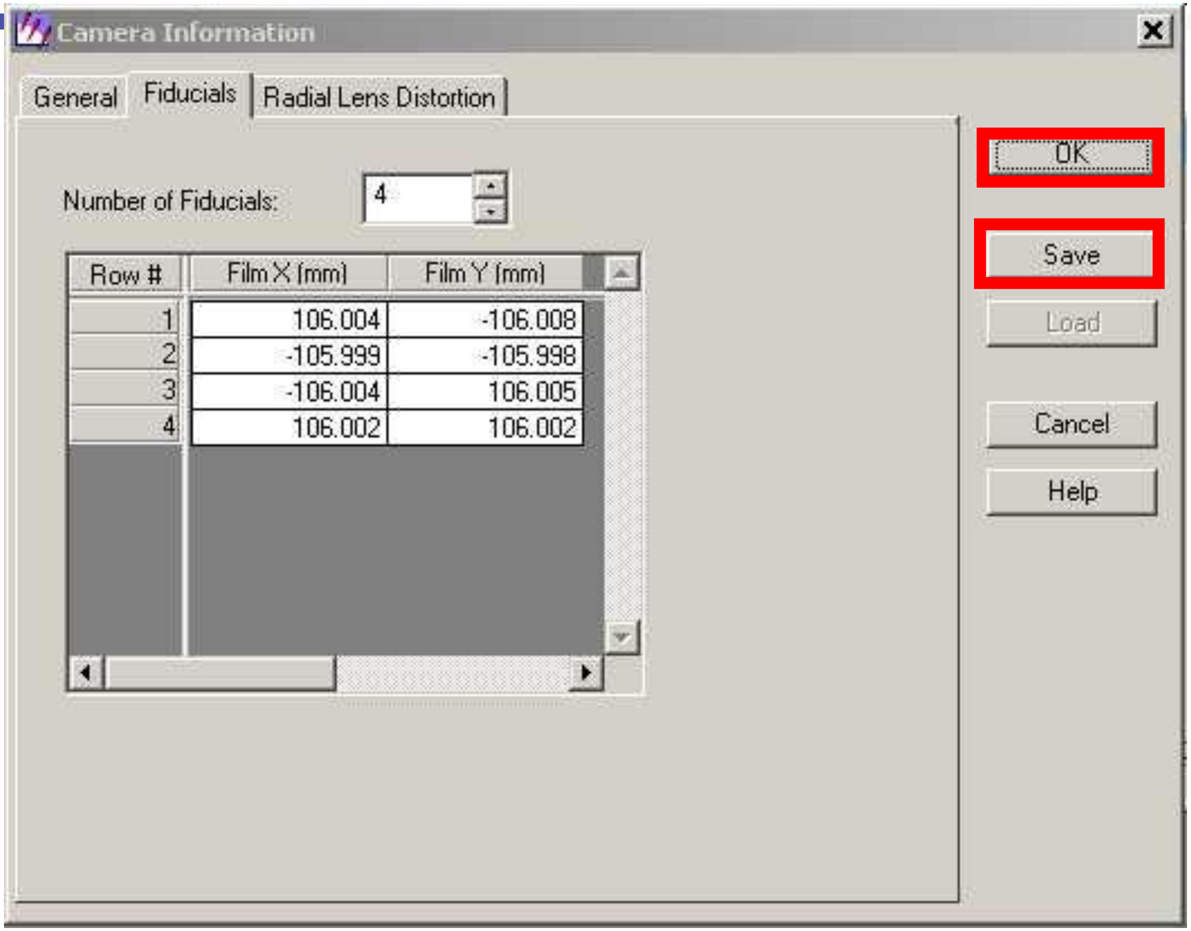
Camera Name: Default Wild

Description: Default Wild Camera

Focal Length (mm): 153.2300

Principal Point xo (mm): 0.0000

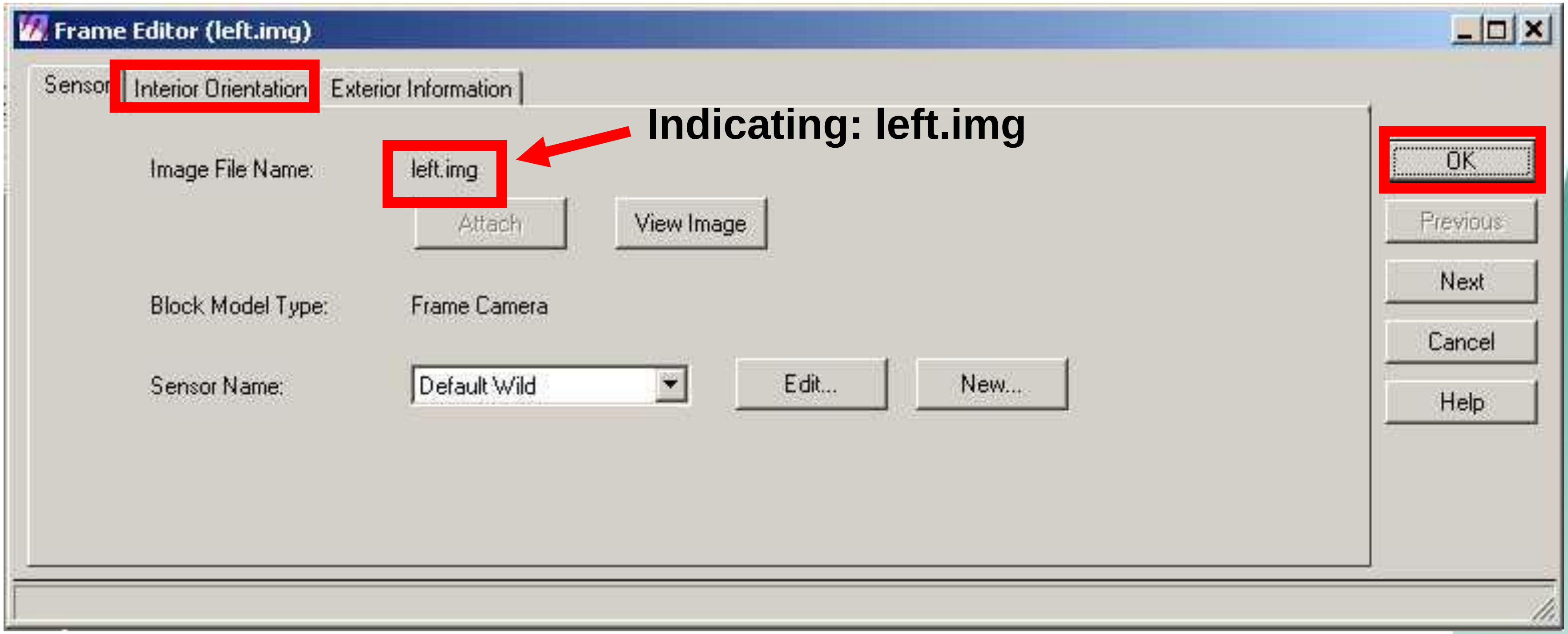
Principal Point yo (mm): 0.0000



Number of Fiducials: 4

Row #	Film X (mm)	Film Y (mm)
1	106.004	-106.008
2	-105.999	-105.998
3	-106.004	106.005
4	106.002	106.002

Interior orientation for left image



Frame Editor (left.img)

Image File Name: left.img

Block Model Type: Frame Camera

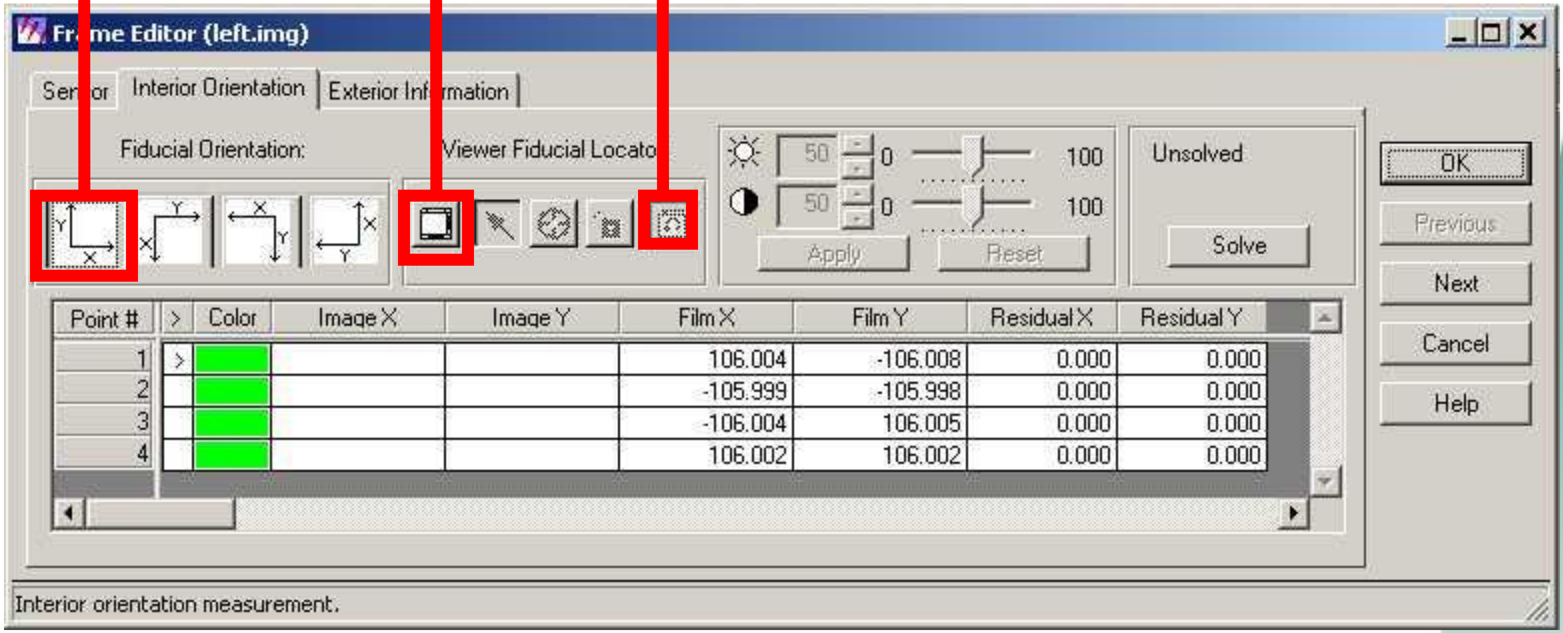
Sensor Name: Default Wild

Indicating: left.img

1st Fiducial point

Jumps automatically to next fiducial point

Load left image

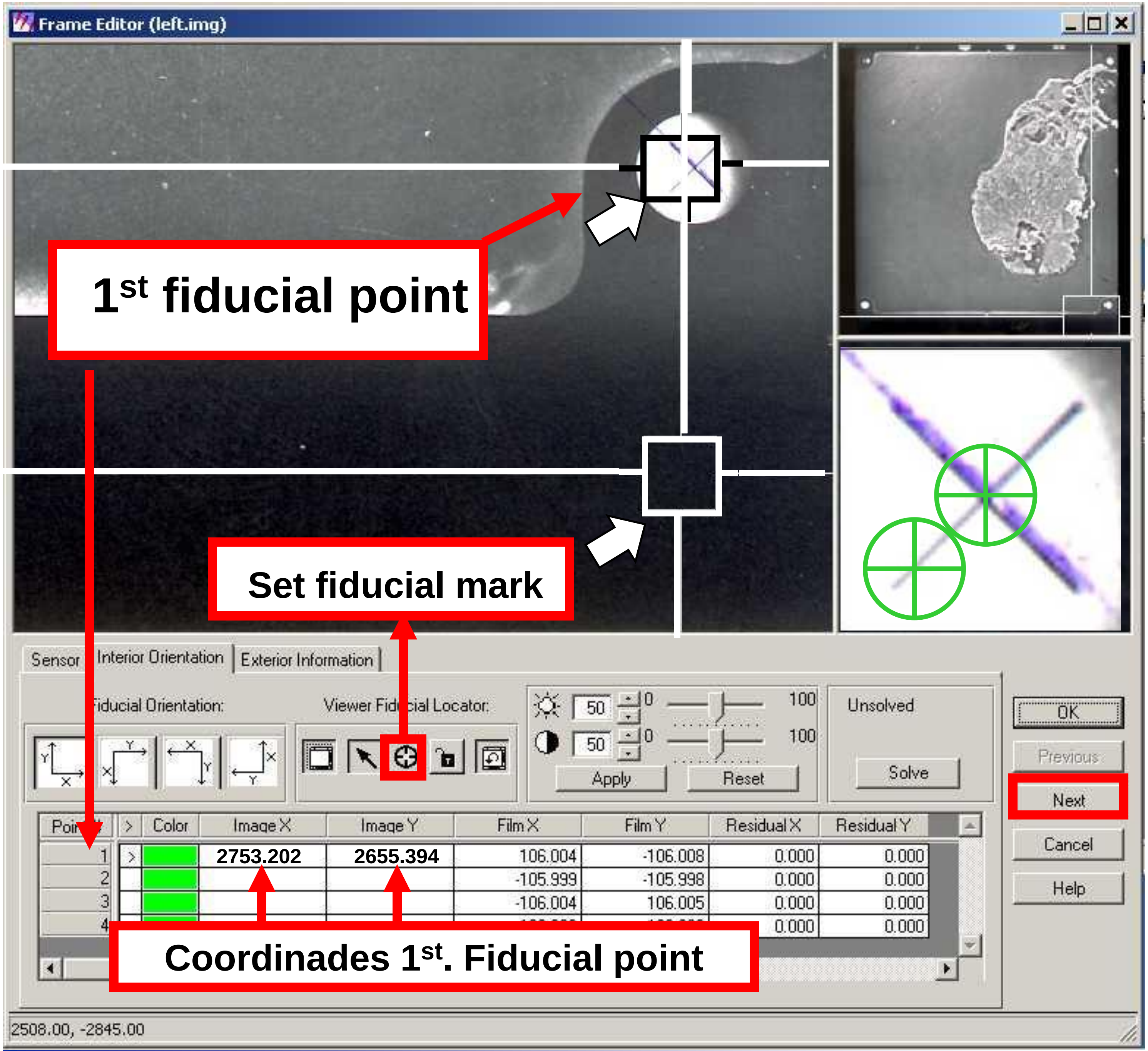


Frame Editor (left.img)

Unsolved

Point #	>	Color	Image X	Image Y	Film X	Film Y	Residual X	Residual Y
1	>	🟩			106.004	-106.008	0.000	0.000
2		🟩			-105.999	-105.998	0.000	0.000
3		🟩			-106.004	106.005	0.000	0.000
4		🟩			106.002	106.002	0.000	0.000

Interior orientation measurement.

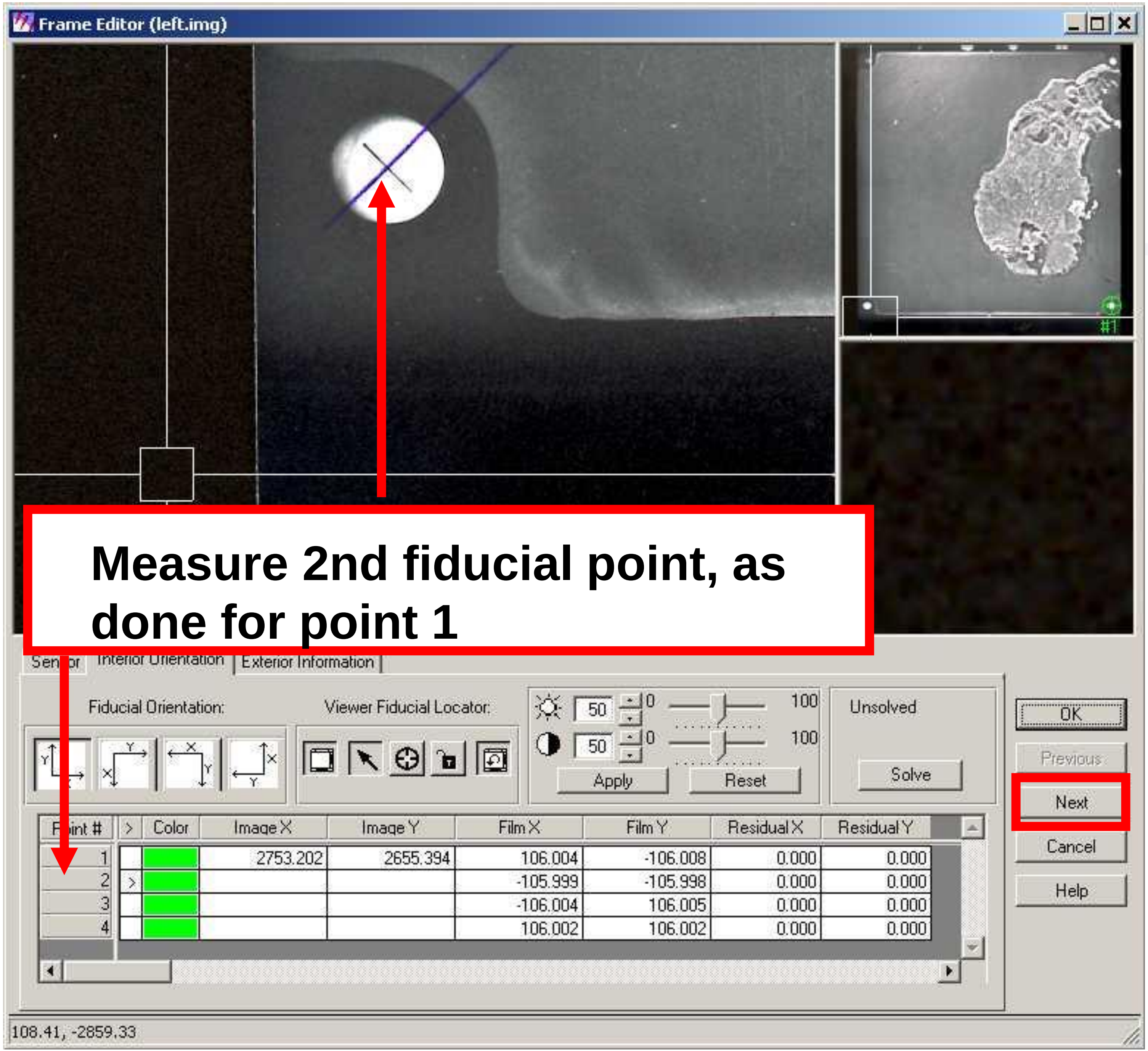


1st fiducial point

Set fiducial mark

Poi	>	Color	Image X	Image Y	Film X	Film Y	Residual X	Residual Y
1	>	🟩	2753.202	2655.394	106.004	-106.008	0.000	0.000
2		🟩			-105.999	-105.998	0.000	0.000
3		🟩			-106.004	106.005	0.000	0.000
4							0.000	0.000

Coordinades 1st. Fiducial point



Measure 2nd fiducial point, as done for point 1

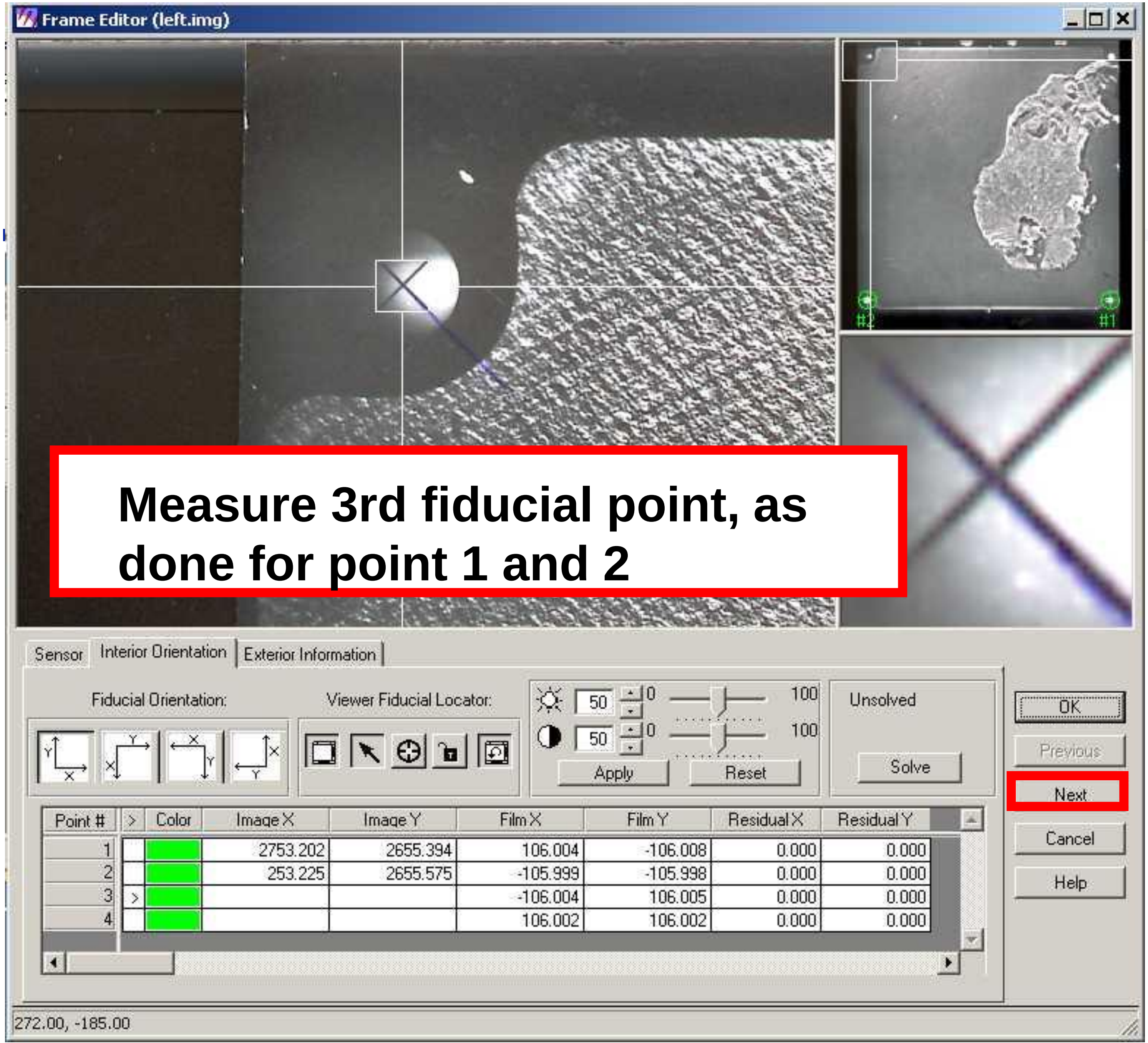
Brightness: 50

Contrast: 50

Unsolved

Point #	>	Color	Image X	Image Y	Film X	Film Y	Residual X	Residual Y
1		🟩	2753.202	2655.394	106.004	-106.008	0.000	0.000
2	>	🟩			-105.999	-105.998	0.000	0.000
3		🟩			-106.004	106.005	0.000	0.000
4		🟩			106.002	106.002	0.000	0.000

108.41, -2859.33

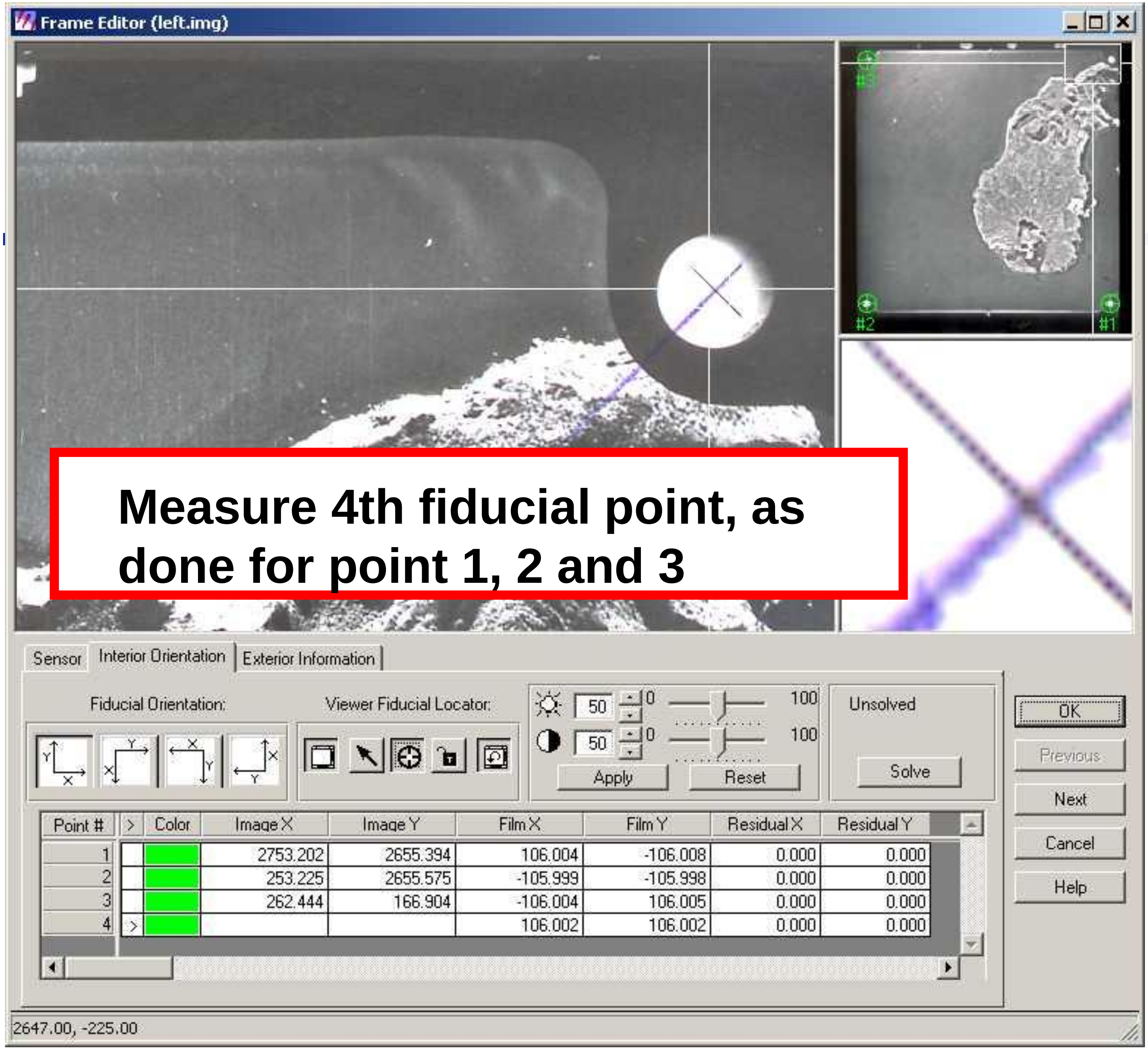


Measure 3rd fiducial point, as done for point 1 and 2

Brightness: 50
Contrast: 50
Unsolved

Point #	>	Color	Image X	Image Y	Film X	Film Y	Residual X	Residual Y
1		🟩	2753.202	2655.394	106.004	-106.008	0.000	0.000
2		🟩	253.225	2655.575	-105.999	-105.998	0.000	0.000
3	>	🟩			-106.004	106.005	0.000	0.000
4		🟩			106.002	106.002	0.000	0.000

272.00, -185.00



Measure 4th fiducial point, as done for point 1, 2 and 3

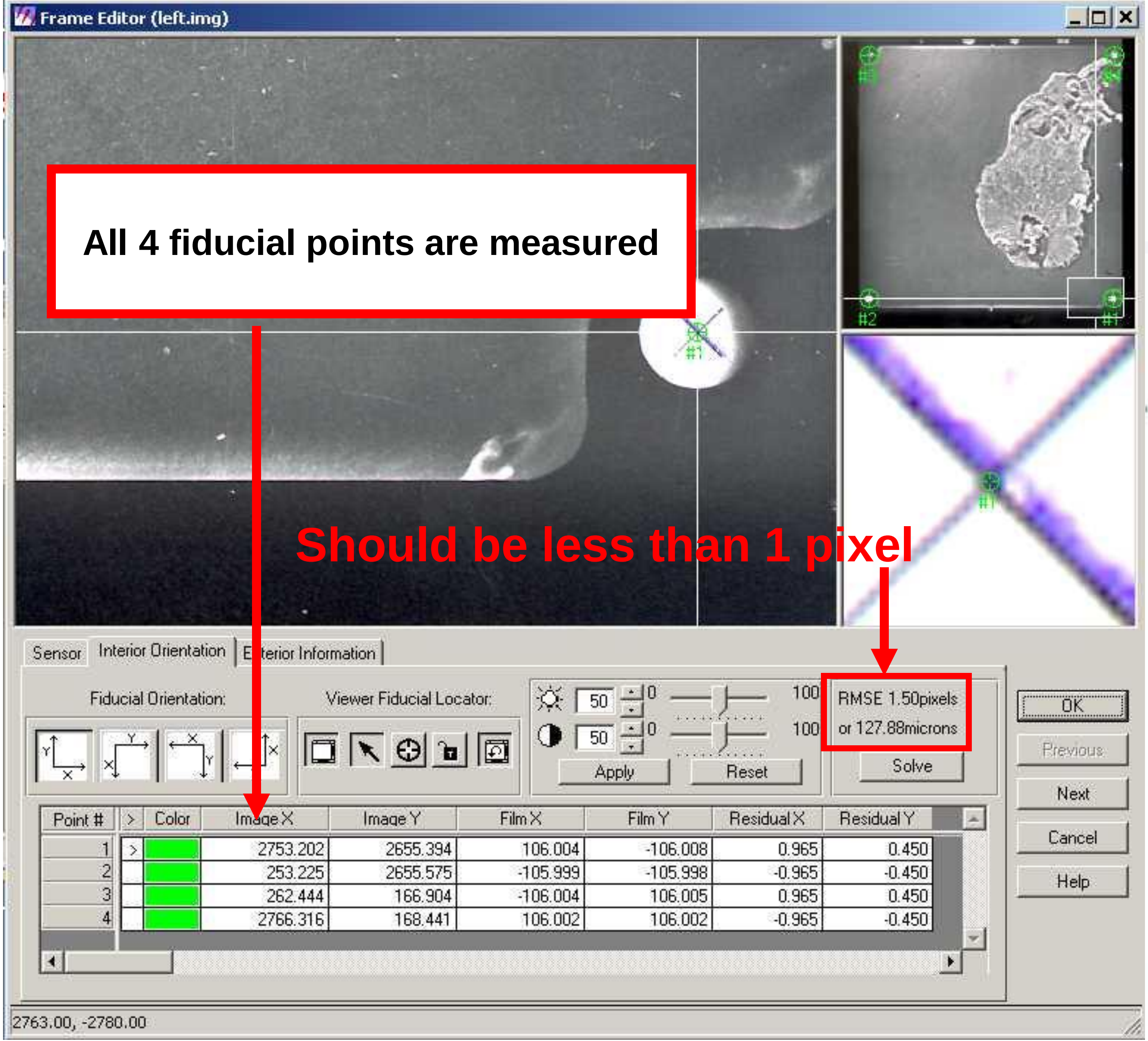
Brightness: 50

Contrast: 50

Unsolved

Point #	>	Color	Image X	Image Y	Film X	Film Y	Residual X	Residual Y
1		🟩	2753.202	2655.394	106.004	-106.008	0.000	0.000
2		🟩	253.225	2655.575	-105.999	-105.998	0.000	0.000
3		🟩	262.444	166.904	-106.004	106.005	0.000	0.000
4	>	🟩			106.002	106.002	0.000	0.000

2647.00, -225.00



All 4 fiducial points are measured

Should be less than 1 pixel

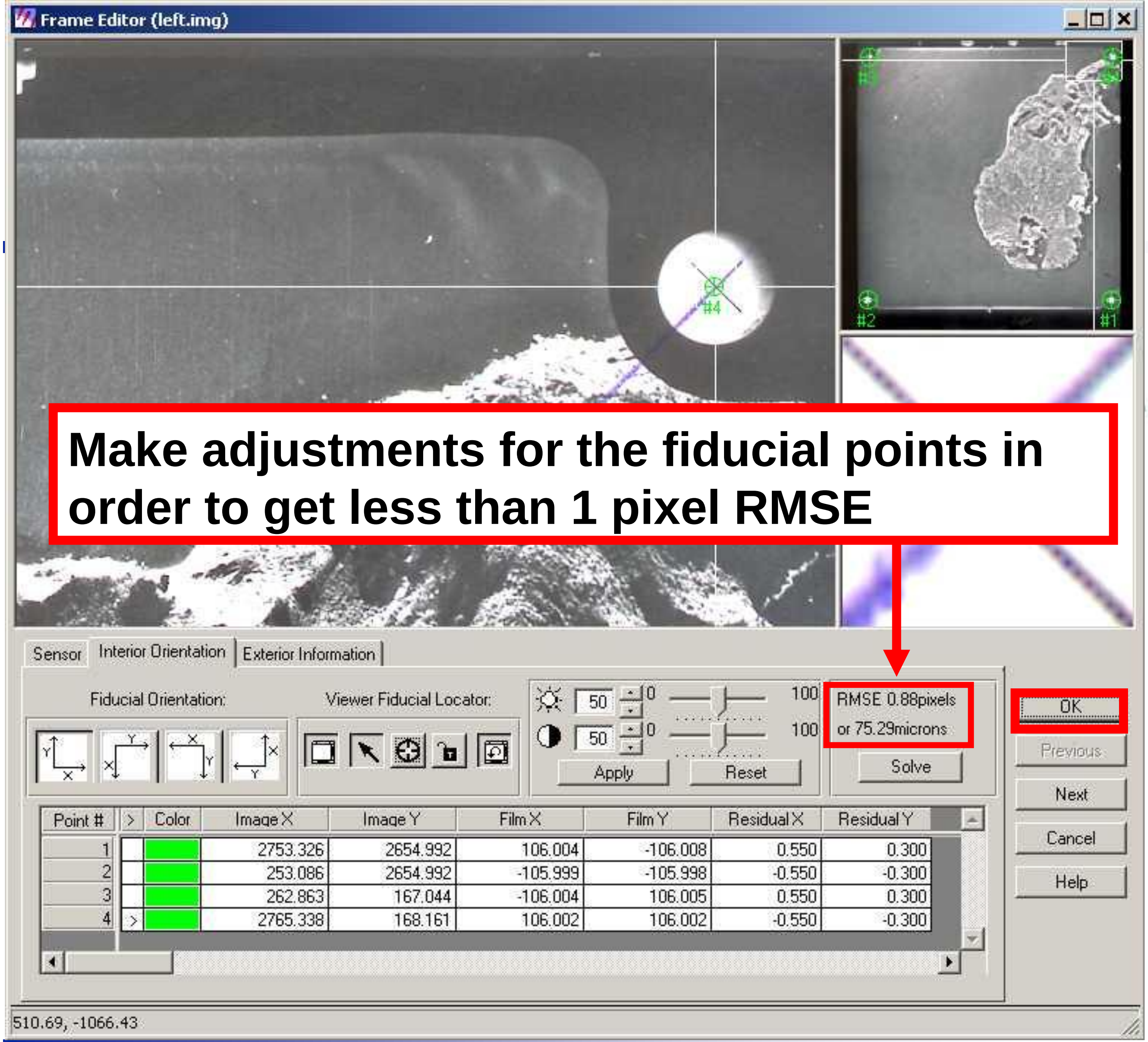
Brightness: 50

Contrast: 50

RMSE 1.50pixels
or 127.88microns

Point #	>	Color	Image X	Image Y	Film X	Film Y	Residual X	Residual Y
1	>	🟩	2753.202	2655.394	106.004	-106.008	0.965	0.450
2		🟩	253.225	2655.575	-105.999	-105.998	-0.965	-0.450
3		🟩	262.444	166.904	-106.004	106.005	0.965	0.450
4		🟩	2766.316	168.441	106.002	106.002	-0.965	-0.450

2763.00, -2780.00



Make adjustments for the fiducial points in order to get less than 1 pixel RMSE

Brightness: 50 (0–100)

Contrast: 50 (0–100)

RMSE 0.88pixels
or 75.29microns

Point #	>	Color	Image X	Image Y	Film X	Film Y	Residual X	Residual Y
1		🟩	2753.326	2654.992	106.004	-106.008	0.550	0.300
2		🟩	253.086	2654.992	-105.999	-105.998	-0.550	-0.300
3		🟩	262.863	167.044	-106.004	106.005	0.550	0.300
4	>	🟩	2765.338	168.161	106.002	106.002	-0.550	-0.300

510.69, -1066.43

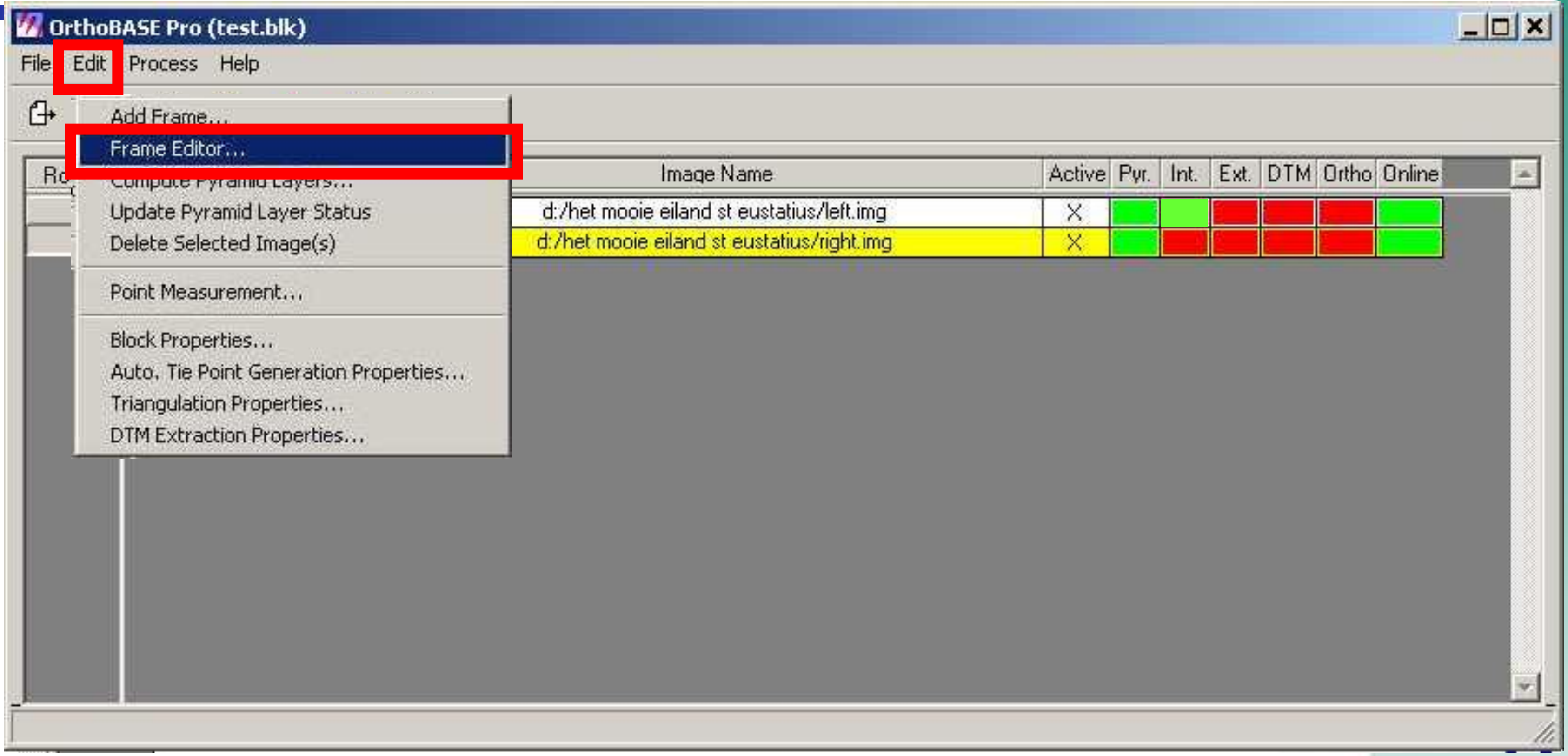

OrthoBASE Pro (test.blk)
File
Edit
Process
Help
Add Frame...
Frame Editor...
Compute Pyramid Layers...
Update Pyramid Layer Status
Delete Selected Image(s)
Point Measurement...
Block Properties...
Auto. Tie Point Generation Properties...
Triangulation Properties...
DTM Extraction Properties...

Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
d:/het mooie eiland st eustatius/left.img	X	🟩	🟩	🟥	🟥	🟥	🟩
d:/het mooie eiland st eustatius/right.img	X	🟩	🟥	🟥	🟥	🟥	🟩

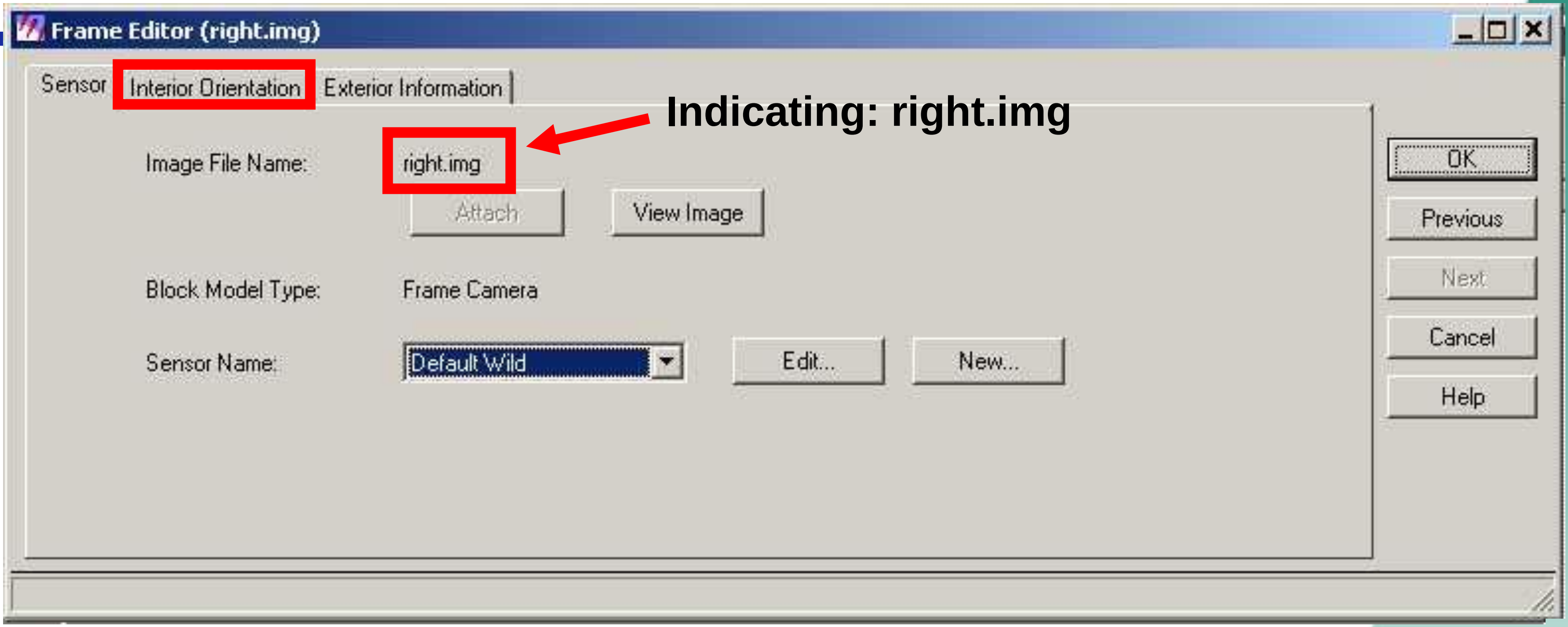


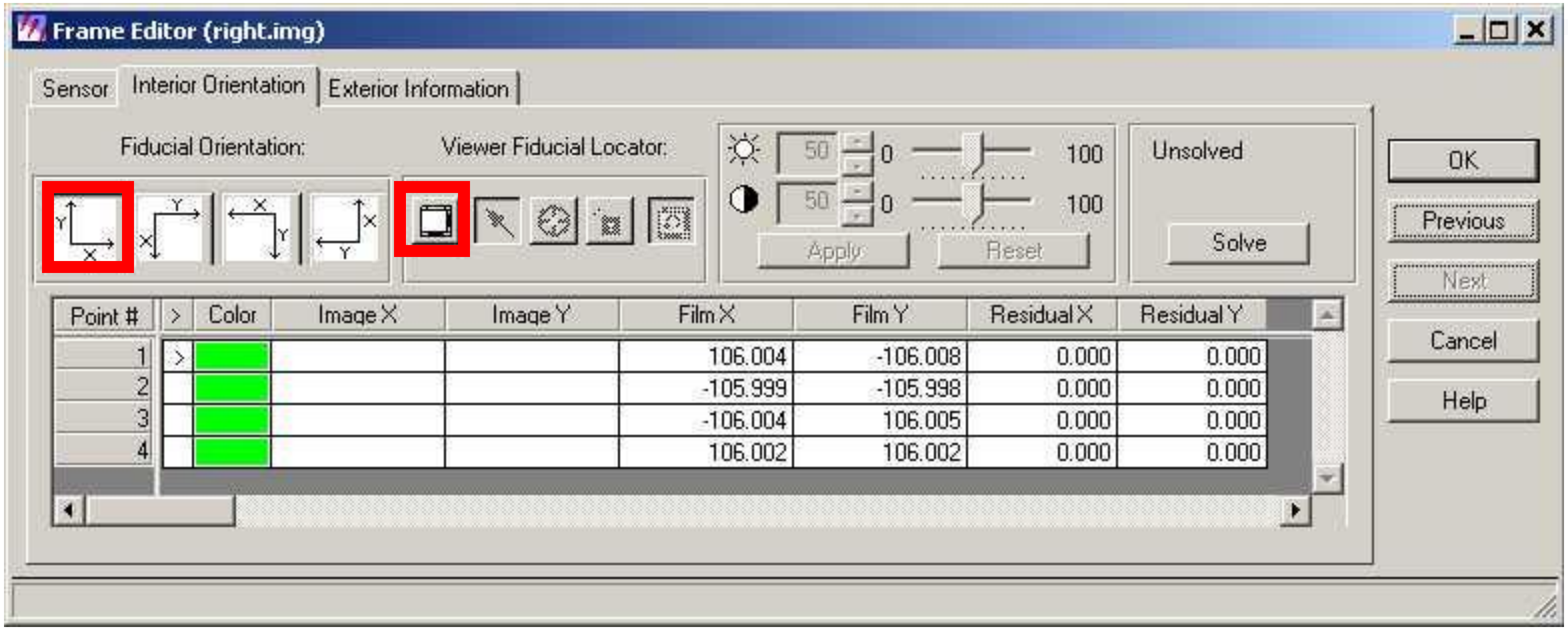
Image File Name: right.img

Block Model Type: Frame Camera

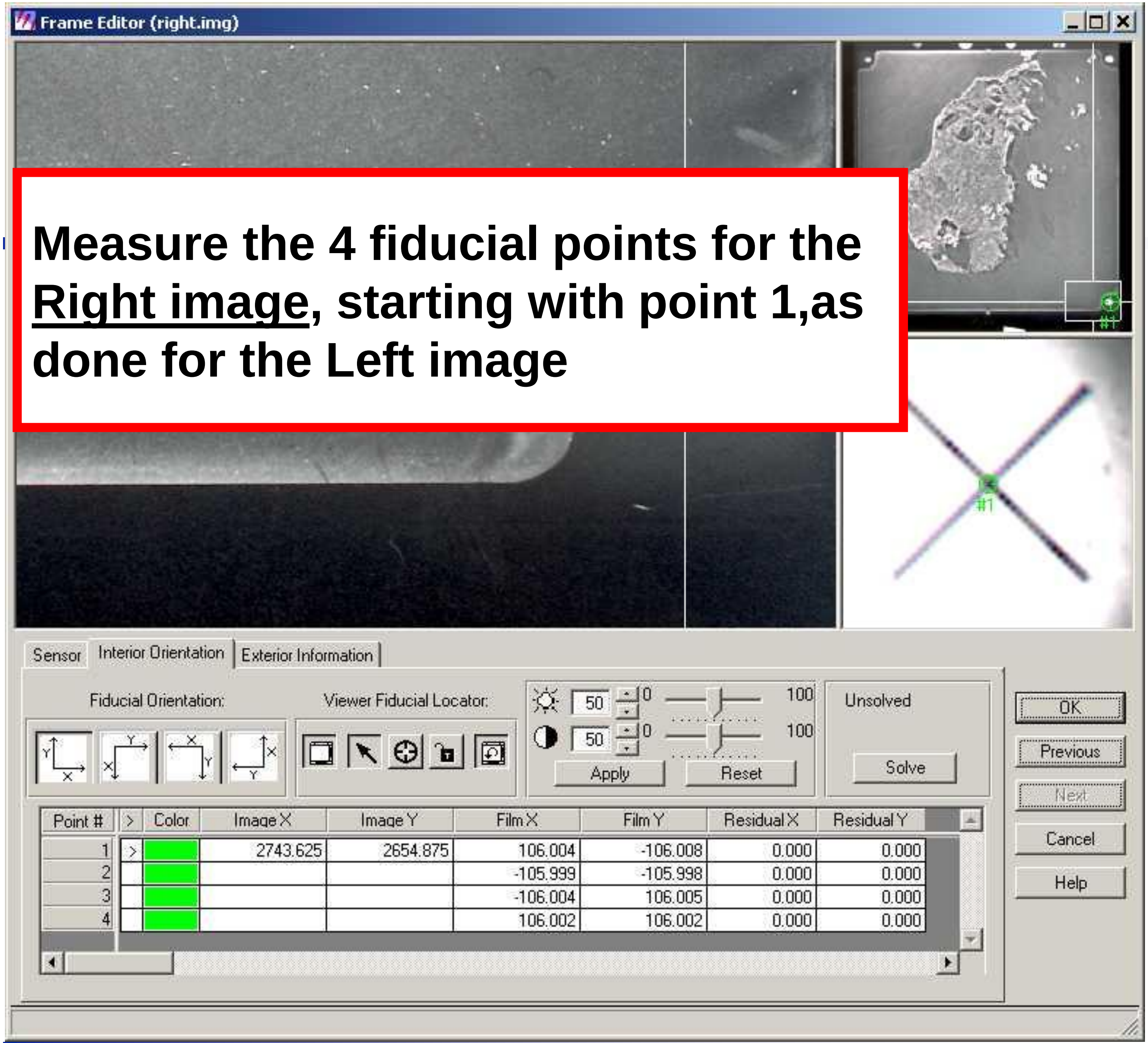
Sensor Name: Default Wild

Indicating: right.img

Interior Orientation for right image



Point #	>	Color	Image X	Image Y	Film X	Film Y	Residual X	Residual Y
1	>	🟩			106.004	-106.008	0.000	0.000
2		🟩			-105.999	-105.998	0.000	0.000
3		🟩			-106.004	106.005	0.000	0.000
4		🟩			106.002	106.002	0.000	0.000



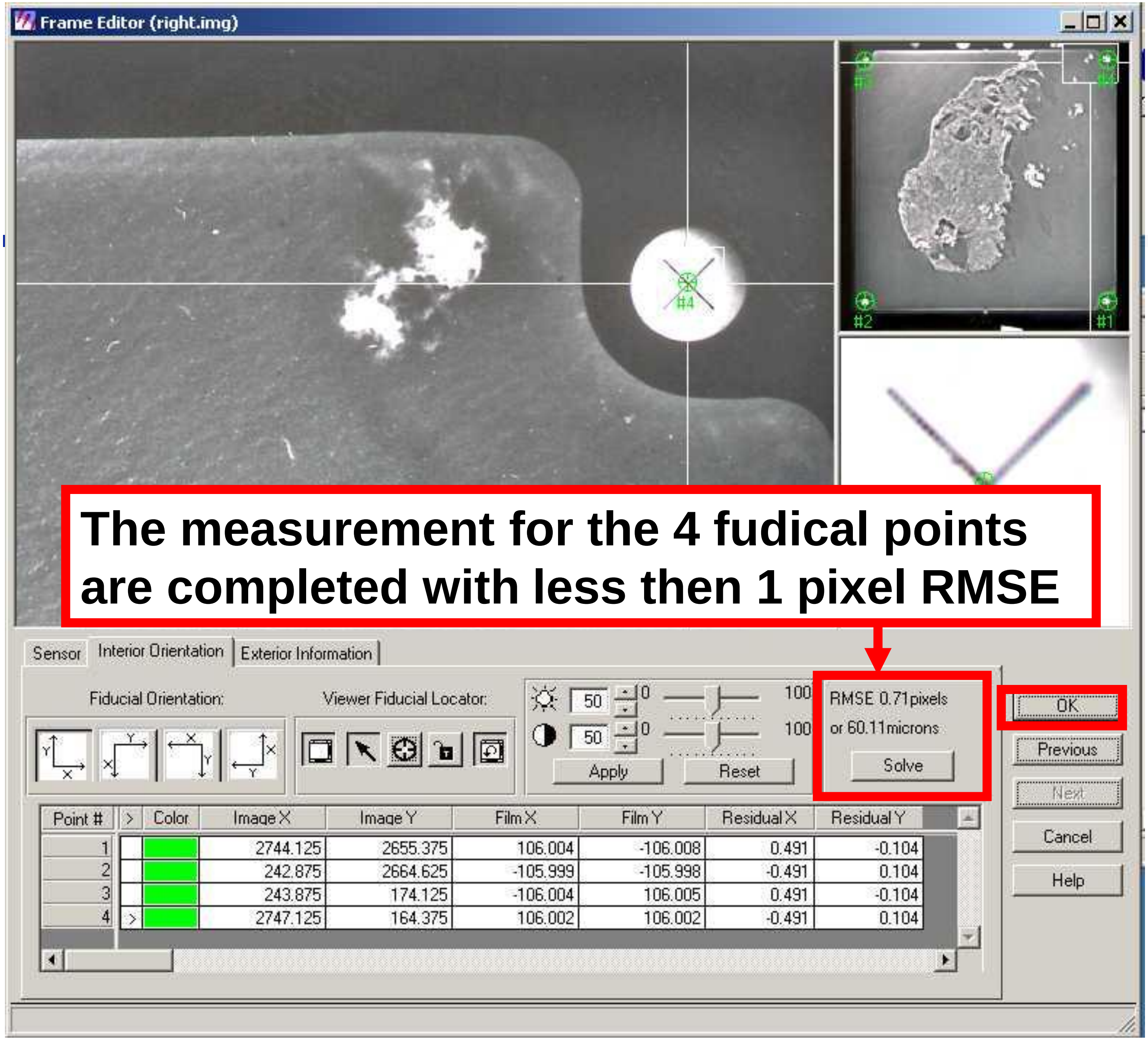
Measure the 4 fiducial points for the Right image, starting with point 1,as done for the Left image

Brightness: 50

Contrast: 50

Unsolved

Point #	>	Color	Image X	Image Y	Film X	Film Y	Residual X	Residual Y
1	>	🟩	2743.625	2654.875	106.004	-106.008	0.000	0.000
2		🟩			-105.999	-105.998	0.000	0.000
3		🟩			-106.004	106.005	0.000	0.000
4		🟩			106.002	106.002	0.000	0.000

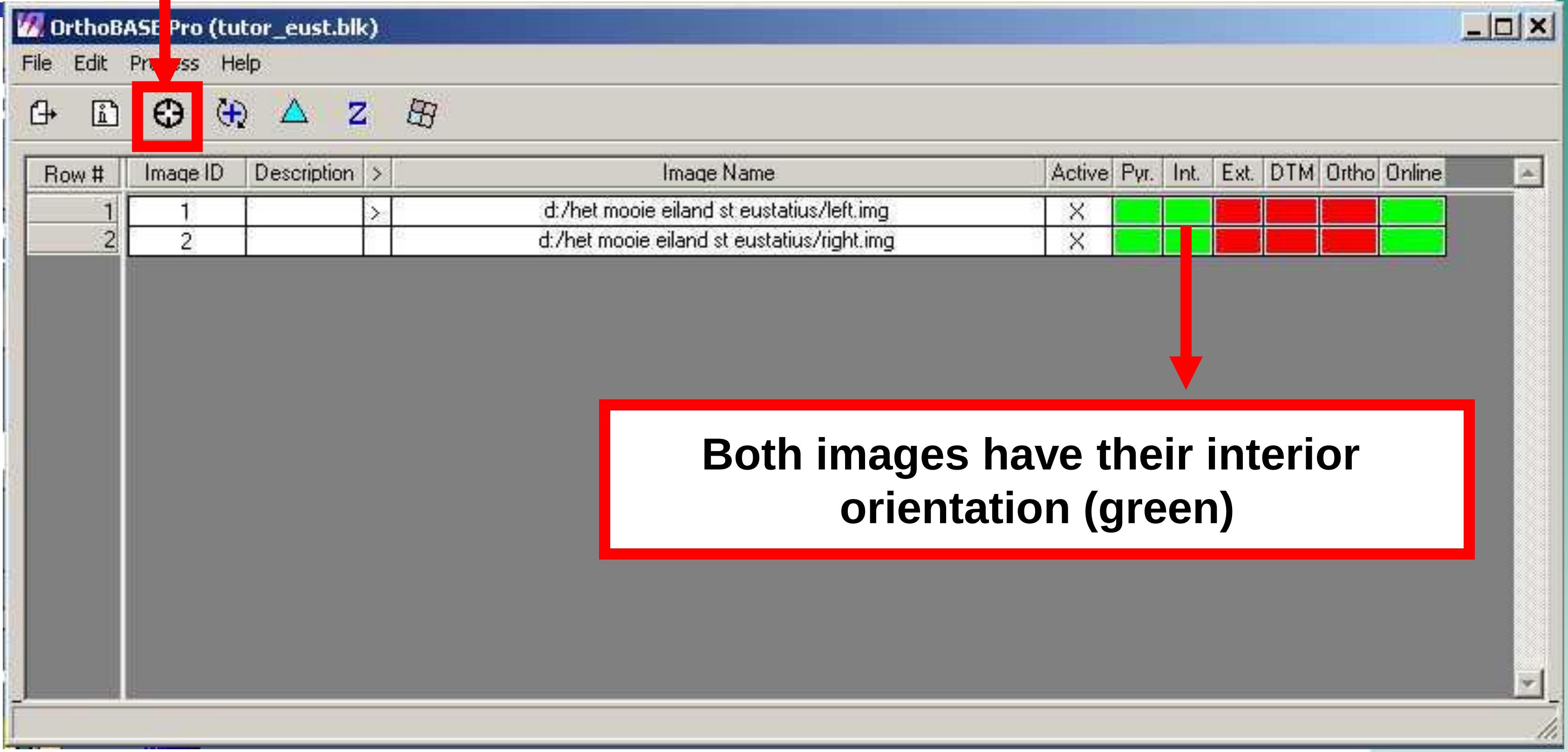


The measurement for the 4 fudical points are completed with less then 1 pixel RMSE

RMSE 0.71pixels
or 60.11microns

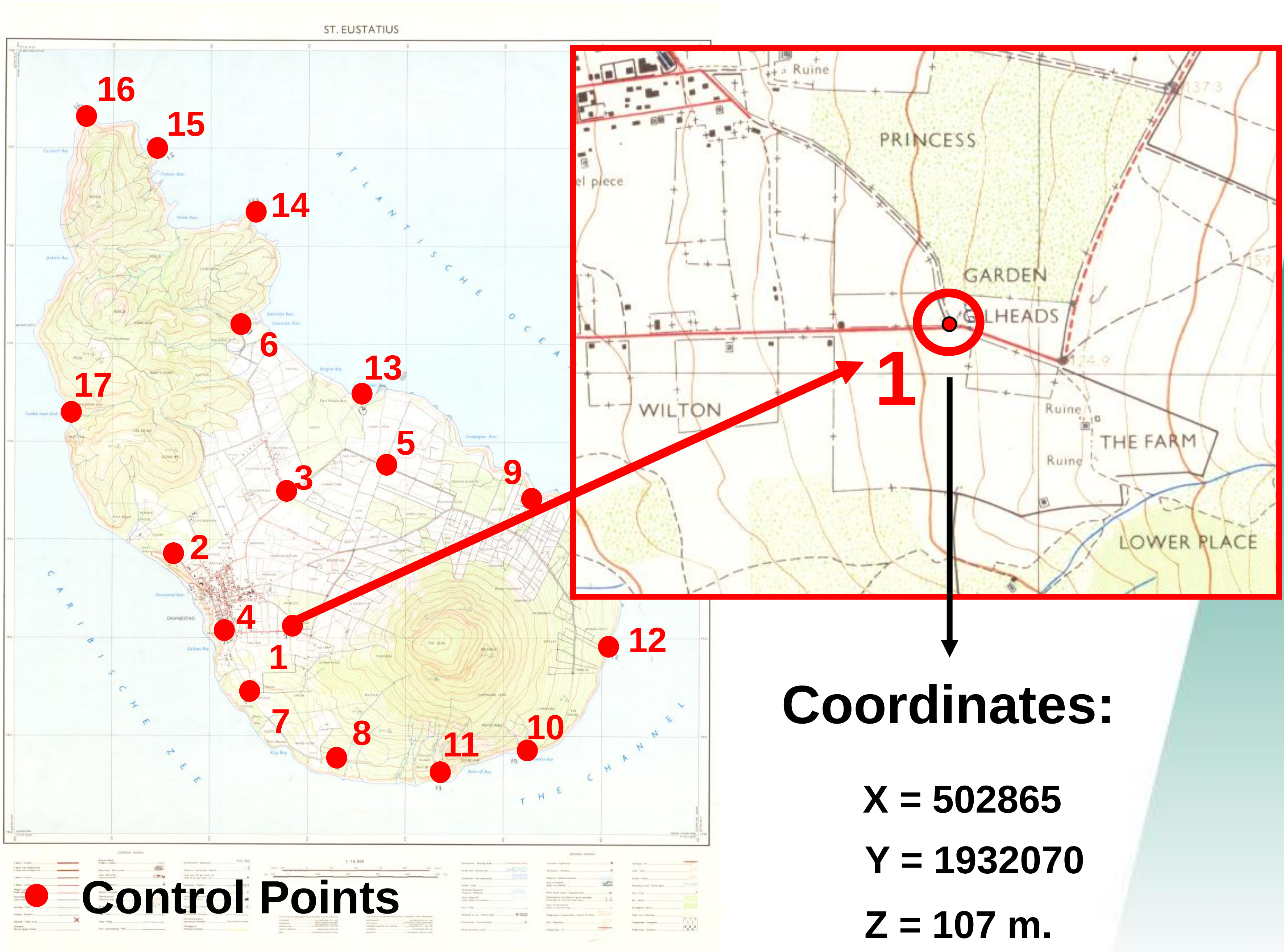
Point #	>	Color	Image X	Image Y	Film X	Film Y	Residual X	Residual Y
1		🟩	2744.125	2655.375	106.004	-106.008	0.491	-0.104
2		🟩	242.875	2664.625	-105.999	-105.998	-0.491	0.104
3		🟩	243.875	174.125	-106.004	106.005	0.491	-0.104
4	>	🟩	2747.125	164.375	106.002	106.002	-0.491	0.104

Set Ground Control Points (GCPs)



Row #	Image ID	Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1		>	d:/het mooie eiland st eustatius/left.img	X	🟩	🟩	🟥	🟥	🟥	🟩
2	2			d:/het mooie eiland st eustatius/right.img	X	🟩	🟩	🟥	🟥	🟥	🟩

Both images have their interior orientation (green)



● **Control Points**

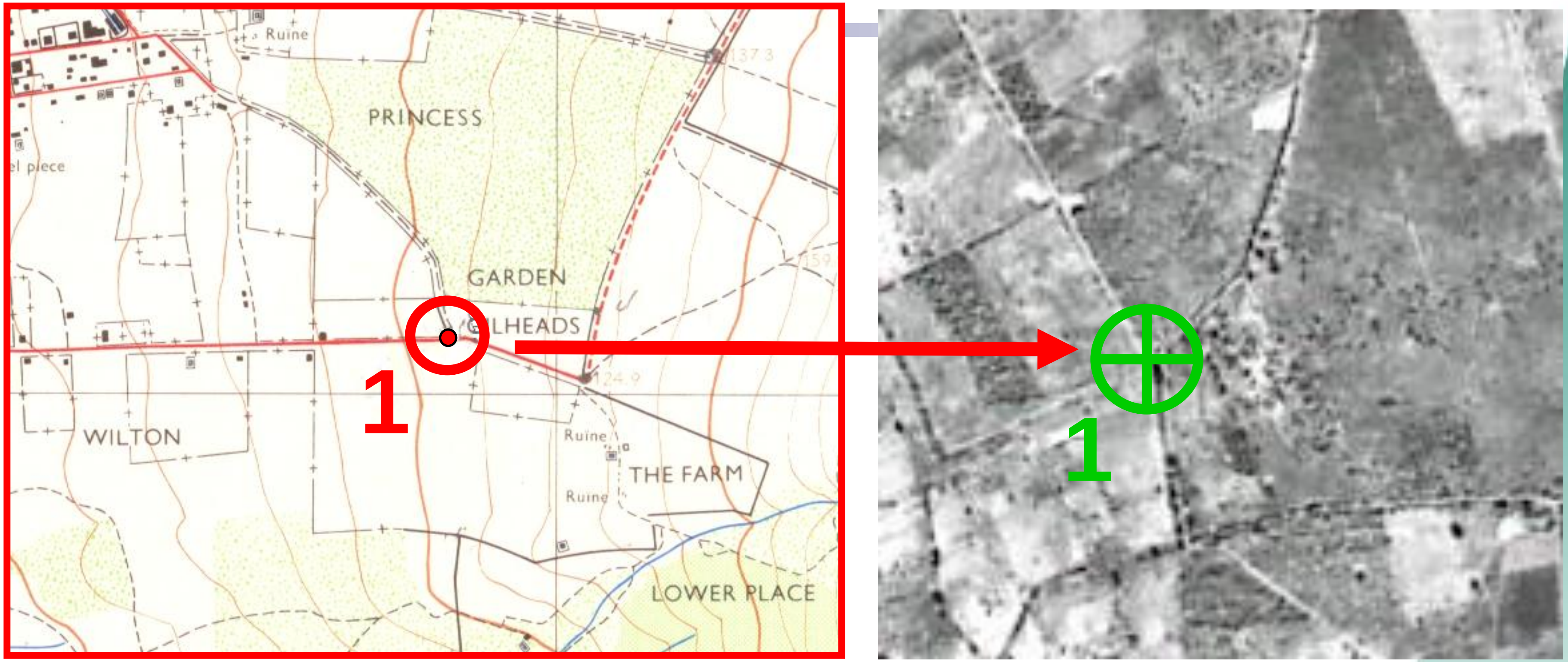
Coordinates:

X = 502865

Y = 1932070

Z = 107 m.

Control Point in map with corresponding point in left image



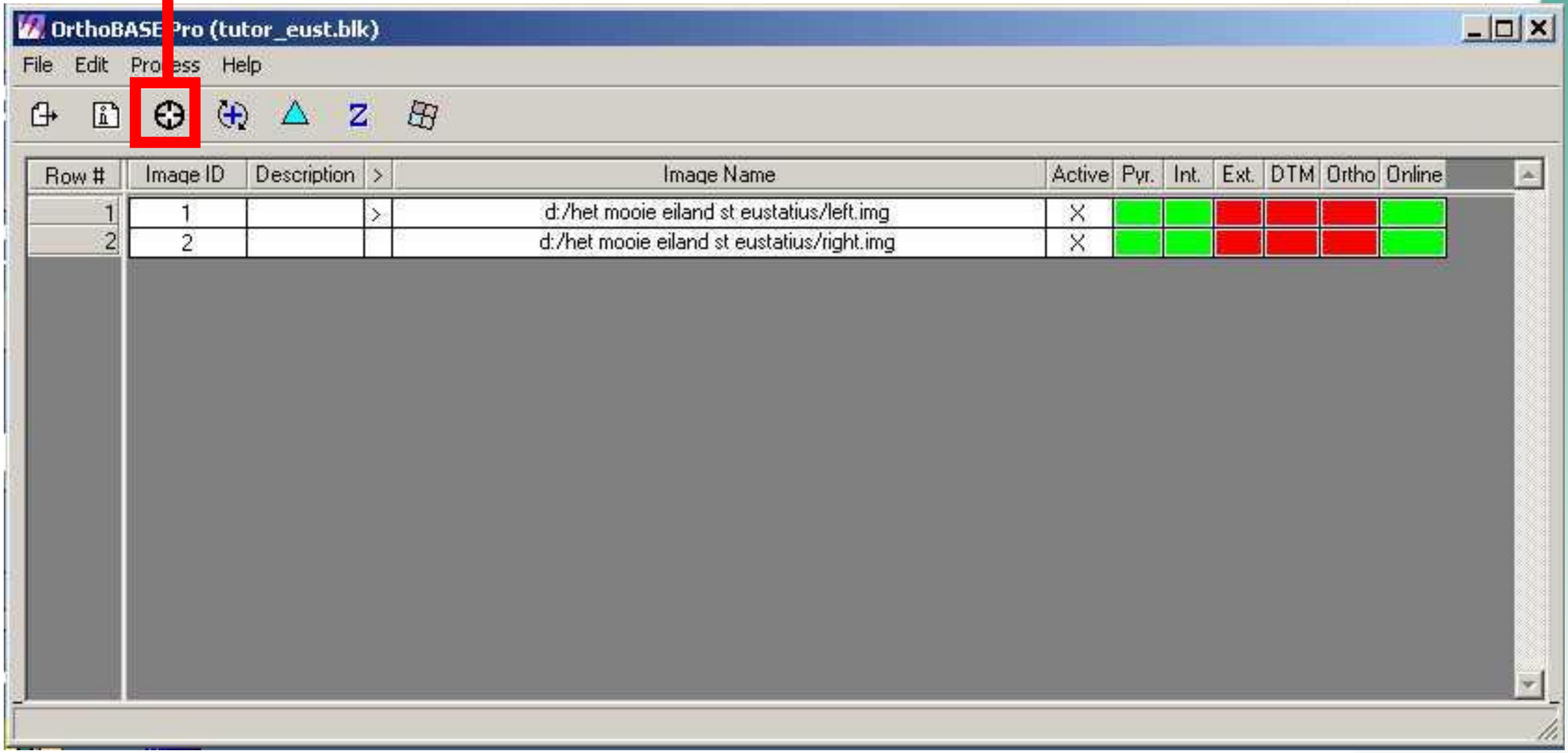
Pnt nr.	X Coordinates	Y Coordinates	Z Value
1	502865	1932070	107
2	501610	1932850	23
3	502775	1933430	52
4	502135	1932060	45
5	503780	1933750	55
6	502265	1935180	20
7	502400	1931430	32

Pnt. Nr.	X coord.	Y coord.	Z value
8	503260	1930760	46
9	505250	1933420	62
10	505190	1930820	10
11	504340	1930600	35
12	506030	1931880	20
13	503515	1934460	0
14	502450	1936998	0

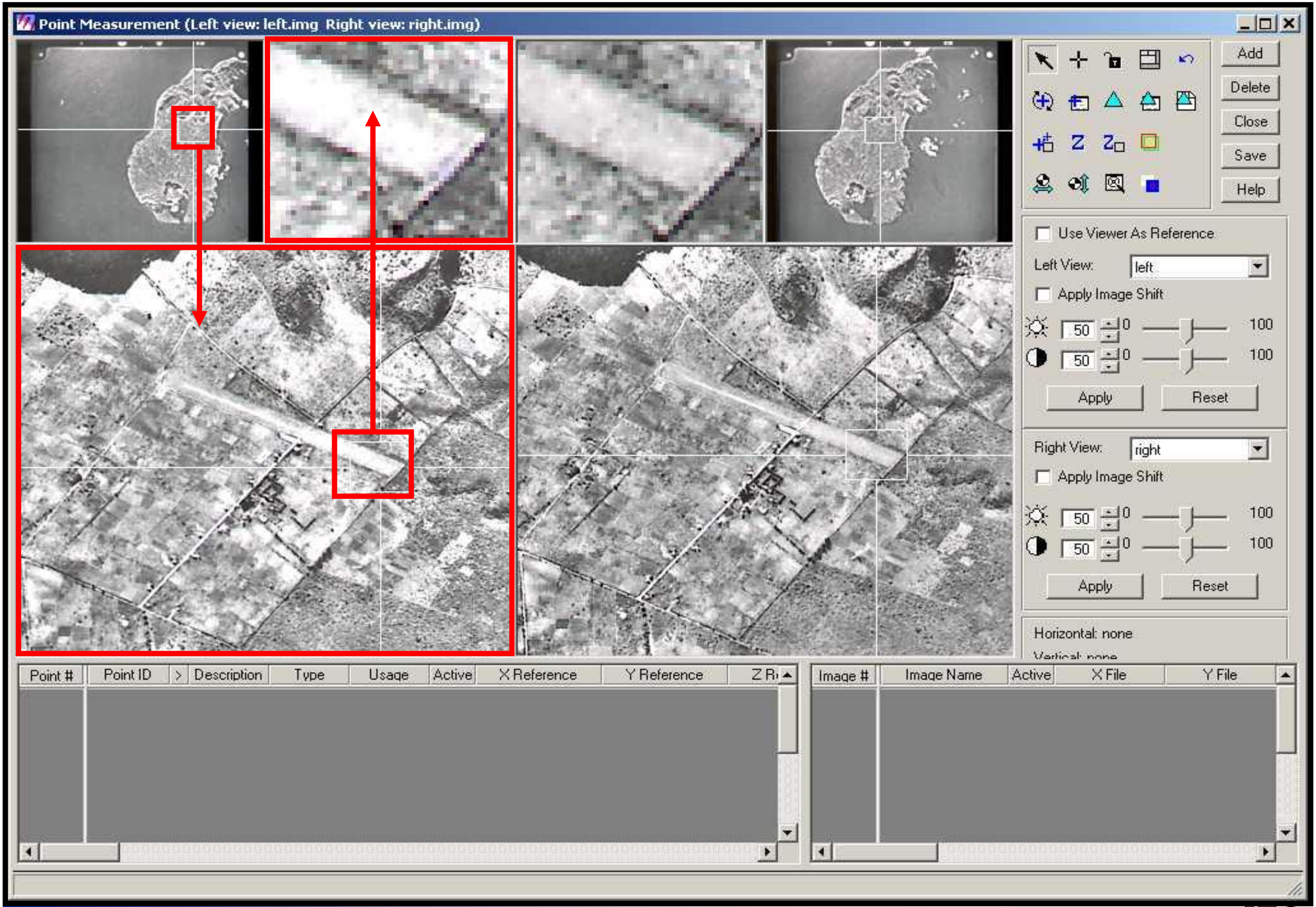
Pnt. Nr.	X coord.	Y coord.	Z value
15	501480	1936998	0
16	500730	1937315	0
17	500570	1934310	0

Measuring Ground Control Points (GCP’s)

Set Ground Control Points (GCPs)



Row #	Image ID	Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1		>	d:/het mooie eiland st eustatius/left.img	X	🟩	🟩	🟥	🟥	🟥	🟩
2	2			d:/het mooie eiland st eustatius/right.img	X	🟩	🟩	🟥	🟥	🟥	🟩



Point Measurement (Left view: left.img Right view: right.img)

☐ Use Viewer As Reference

Left View: left

☐ Apply Image Shift

50 0 100

50 0 100

Right View: right

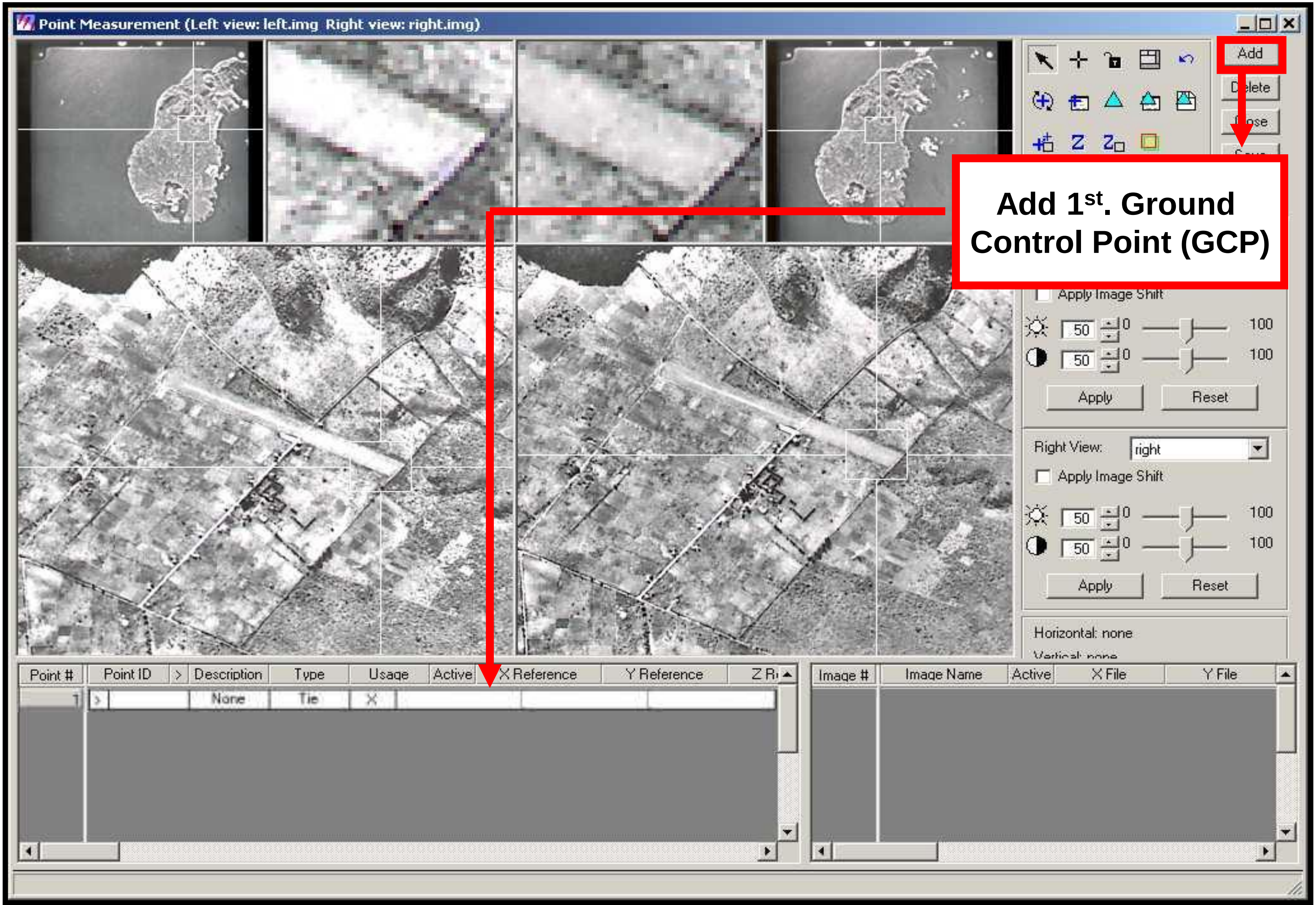
☐ Apply Image Shift

50 0 100

50 0 100

Horizontal: none

Vertical: none


Point Measurement (Left view: left.img Right view: right.img)
Add
Delete
Close
Save
Apply
Reset
Apply
Reset

Add 1st. Ground Control Point (GCP)

☐ Apply Image Shift

Right View: right

☐ Apply Image Shift

Brightness: 50 (0–100)

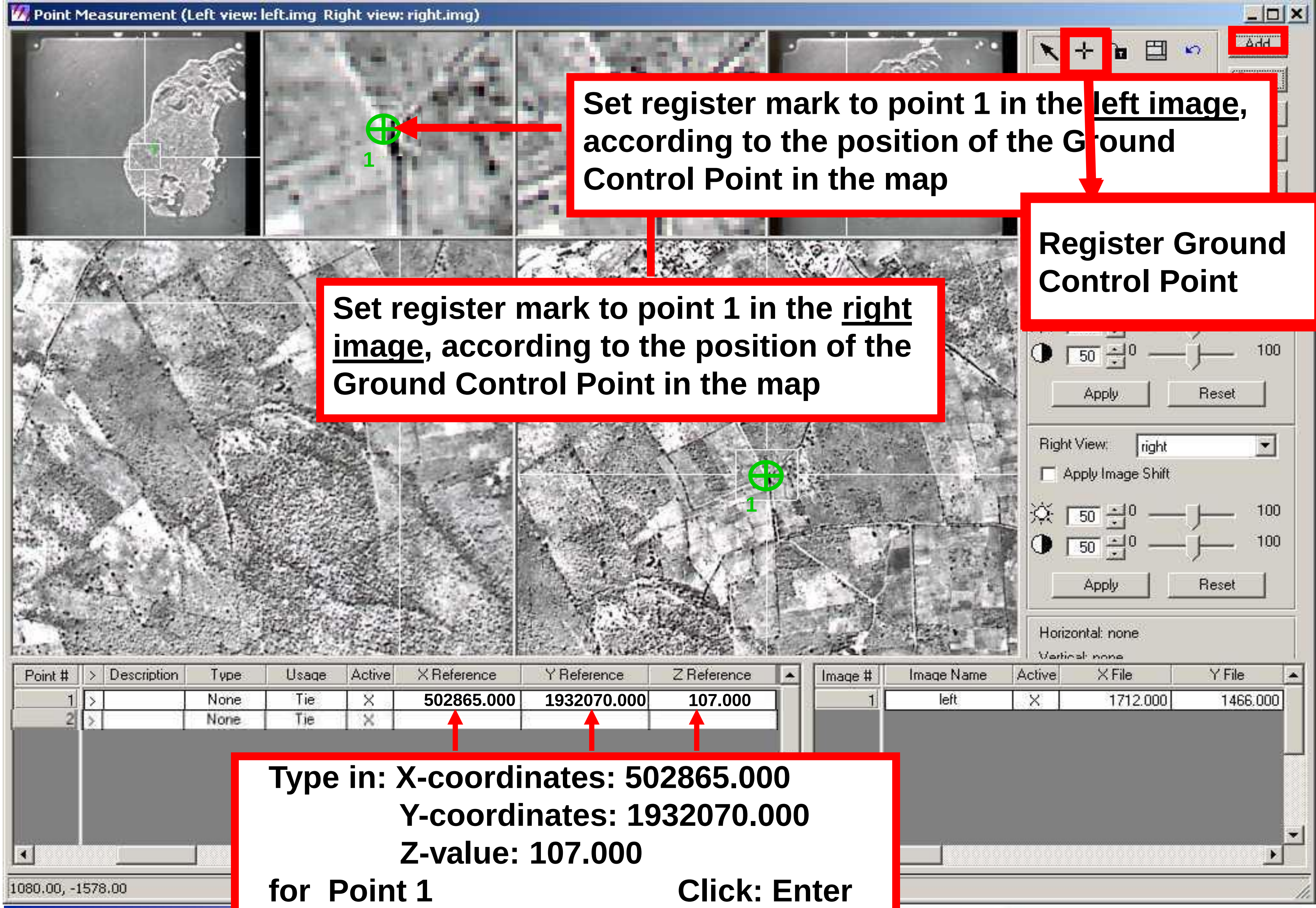
Contrast: 50 (0–100)

Horizontal: none

Vertical: none

Point #	Point ID	>	Description	Type	Usage	Active	X Reference	Y Reference	Z R
1	>		None	Tie	X				

Image #	Image Name	Active	X File	Y File


Point Measurement (Left view: left.img Right view: right.img)
Add
1
1
Apply
Reset
Apply
Reset

Set register mark to point 1 in the **left image**, according to the position of the Ground Control Point in the map

Register Ground Control Point

Set register mark to point 1 in the **right image**, according to the position of the Ground Control Point in the map

Right View: right

☐ Apply Image Shift

50 0 100

50 0 100

Horizontal: none

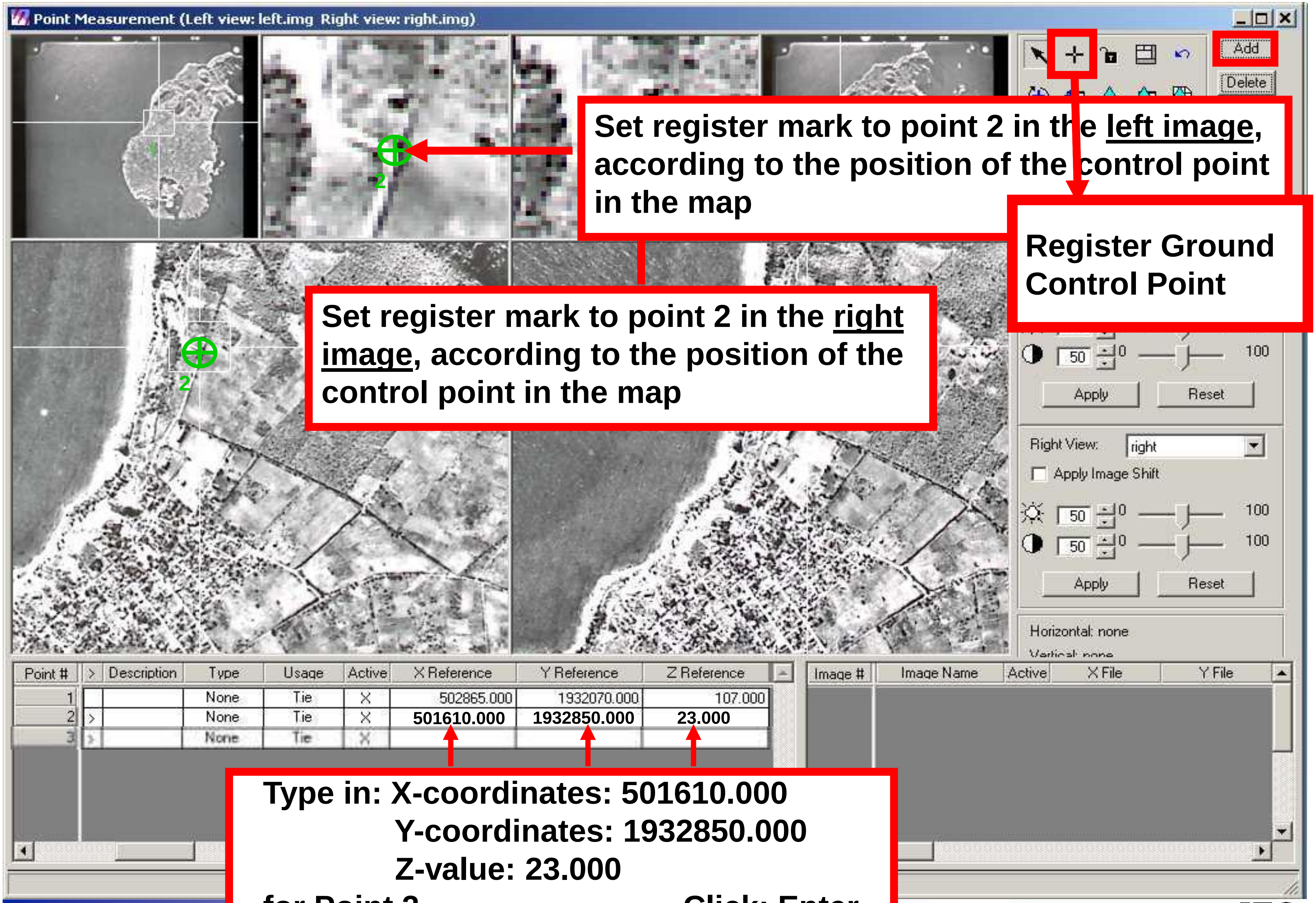
Vertical: none

Point #	>	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference
1	>		None	Tie	X	502865.000	1932070.000	107.000
2	>		None	Tie	X			

Image #	Image Name	Active	X File	Y File
1	left	X	1712.000	1466.000

1080.00, -1578.00

Type in: X-coordinates: 502865.000
Y-coordinates: 1932070.000
Z-value: 107.000
for Point 1 Click: Enter



Point Measurement (Left view: left.img Right view: right.img)

50 0 100

Right View: right

☐ Apply Image Shift

50 0 100

50 0 100

Horizontal: none

Vertical: none

Point #	>	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference
1			None	Tie	X	502865.000	1932070.000	107.000
2	>		None	Tie	X	501610.000	1932850.000	23.000
3	>		None	Tie	X			

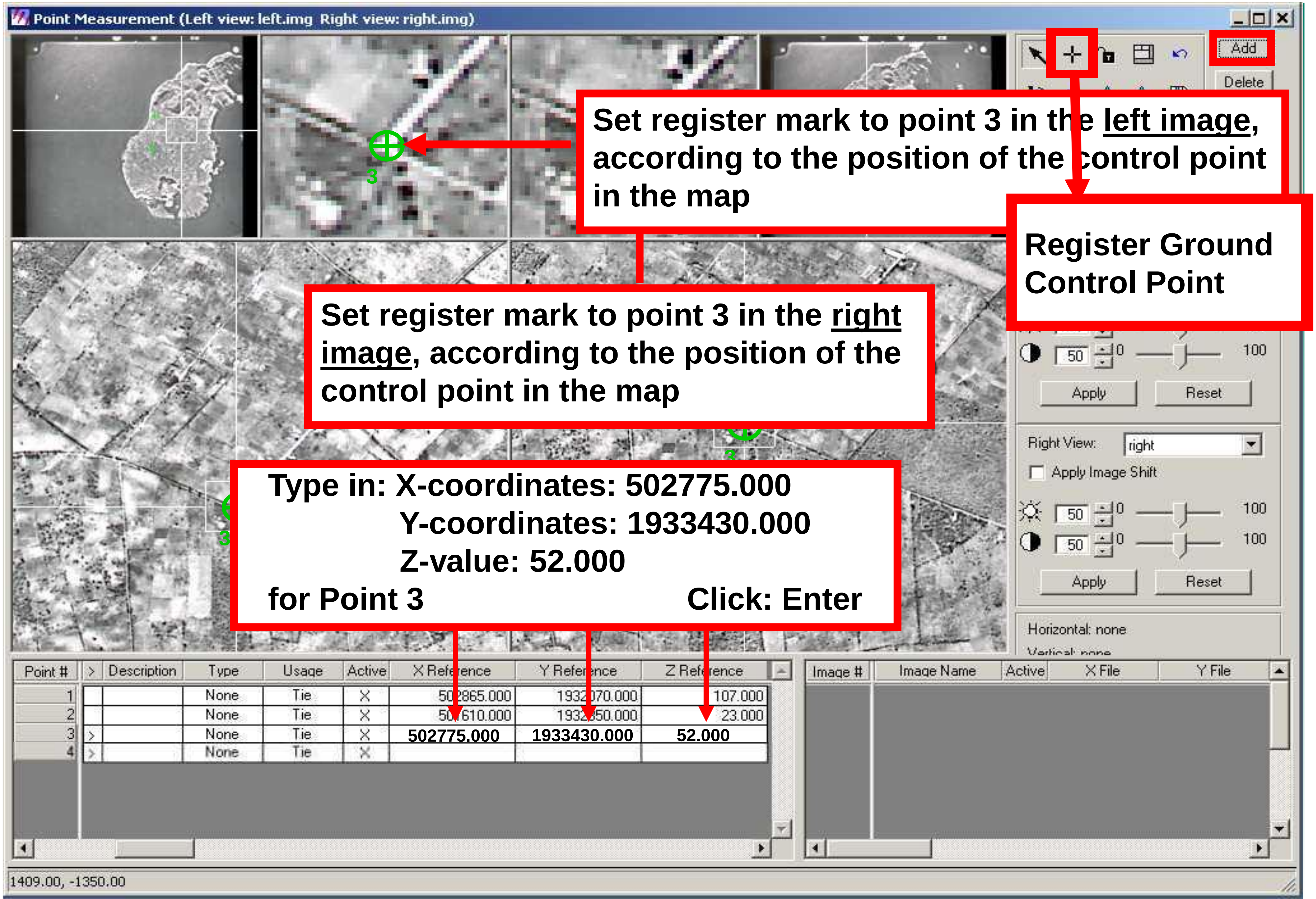
Image #	Image Name	Active	X File	Y File

Set register mark to point 2 in the left image, according to the position of the control point in the map

Register Ground Control Point

Set register mark to point 2 in the right image, according to the position of the control point in the map

Type in: X-coordinates: 501610.000
Y-coordinates: 1932850.000
Z-value: 23.000
for Point 2 Click: Enter



Set register mark to point 3 in the left image, according to the position of the control point in the map

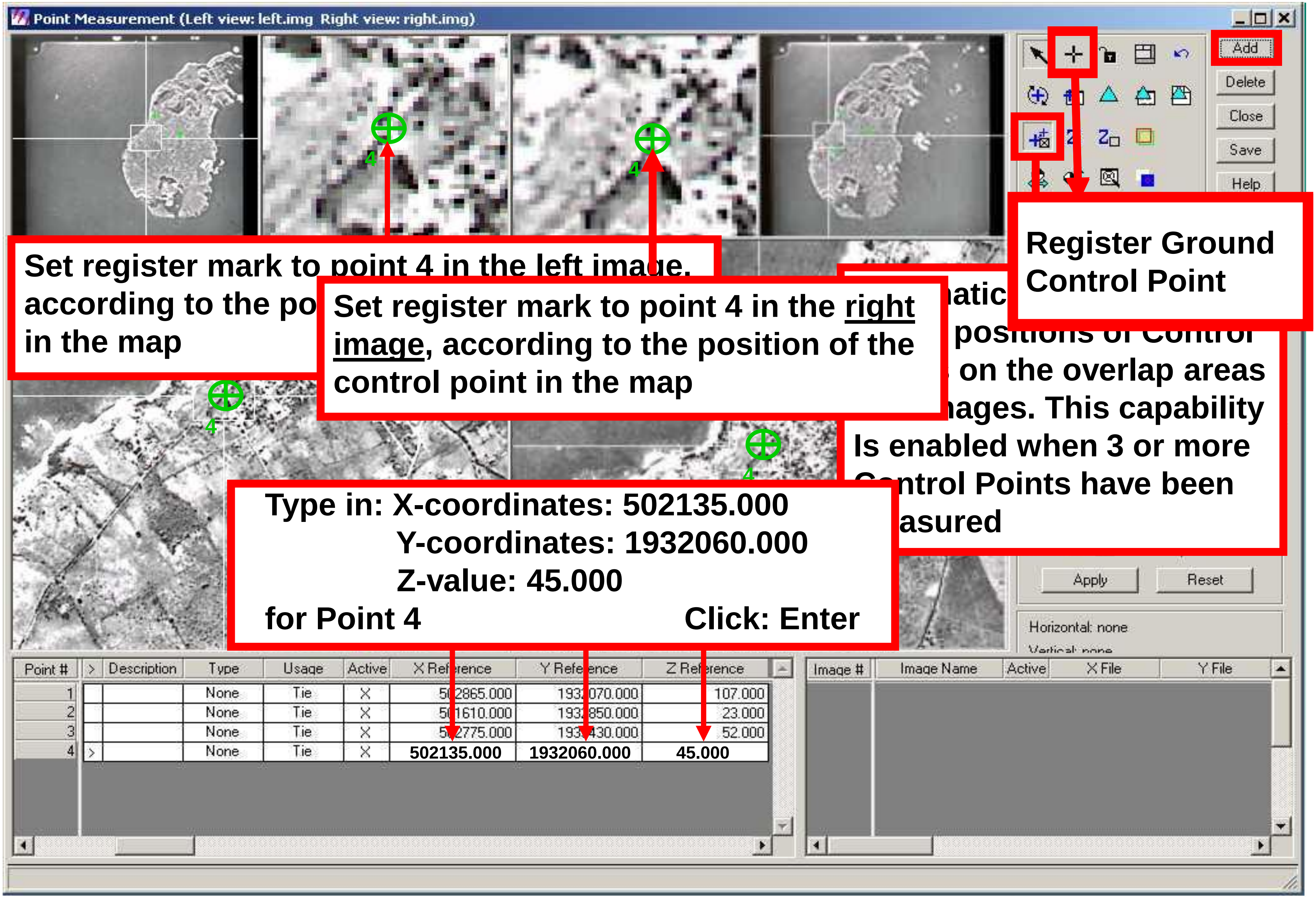
Register Ground Control Point

Set register mark to point 3 in the right image, according to the position of the control point in the map

Type in: X-coordinates: 502775.000
Y-coordinates: 1933430.000
Z-value: 52.000
for Point 3 Click: Enter

Point #	>	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference
1			None	Tie	X	502865.000	1932070.000	107.000
2			None	Tie	X	50[illegible]610.000	1932[illegible]50.000	23.000
3	>		None	Tie	X	**502775.000**	**1933430.000**	**52.000**
4	>		None	Tie	X			

Image #	Image Name	Active	X File	Y File



Set register mark to point 4 in the left image. according to the po in the map

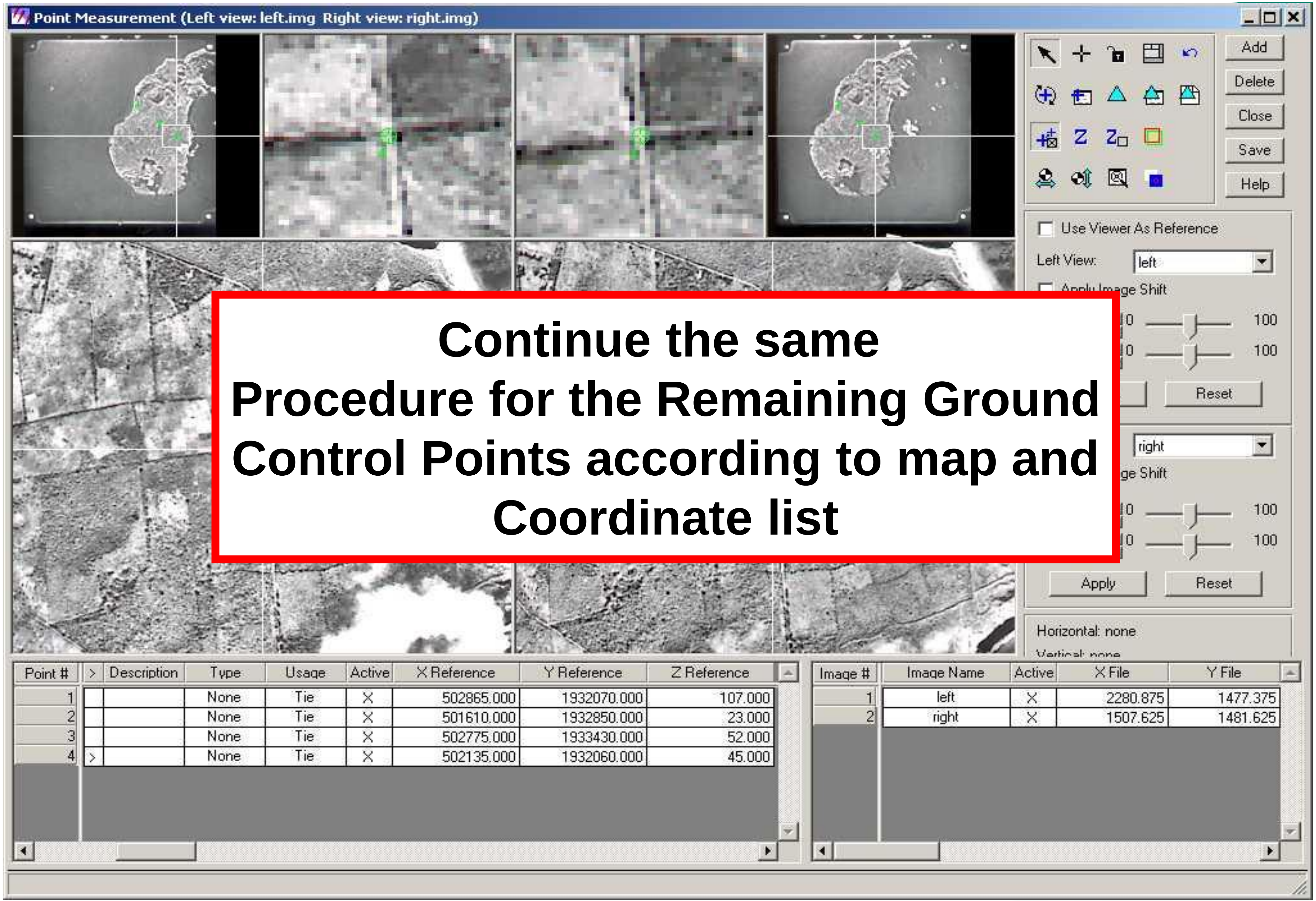
Set register mark to point 4 in the right image, according to the position of the control point in the map

Register Ground Control Point

atic positions of Control on the overlap areas ages. This capability Is enabled when 3 or more Control Points have been asured

Type in: X-coordinates: 502135.000
Y-coordinates: 1932060.000
Z-value: 45.000
for Point 4 Click: Enter

Point #	>	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference
1			None	Tie	X	5 2865.000	193 070.000	107.000
2			None	Tie	X	5 1610.000	193 850.000	23.000
3			None	Tie	X	5 2775.000	193 430.000	52.000
4	>		None	Tie	X	502135.000	1932060.000	45.000



Point Measurement (Left view: left.img Right view: right.img)

☐ Use Viewer As Reference

Left View: left

☐ Apply Image Shift

right

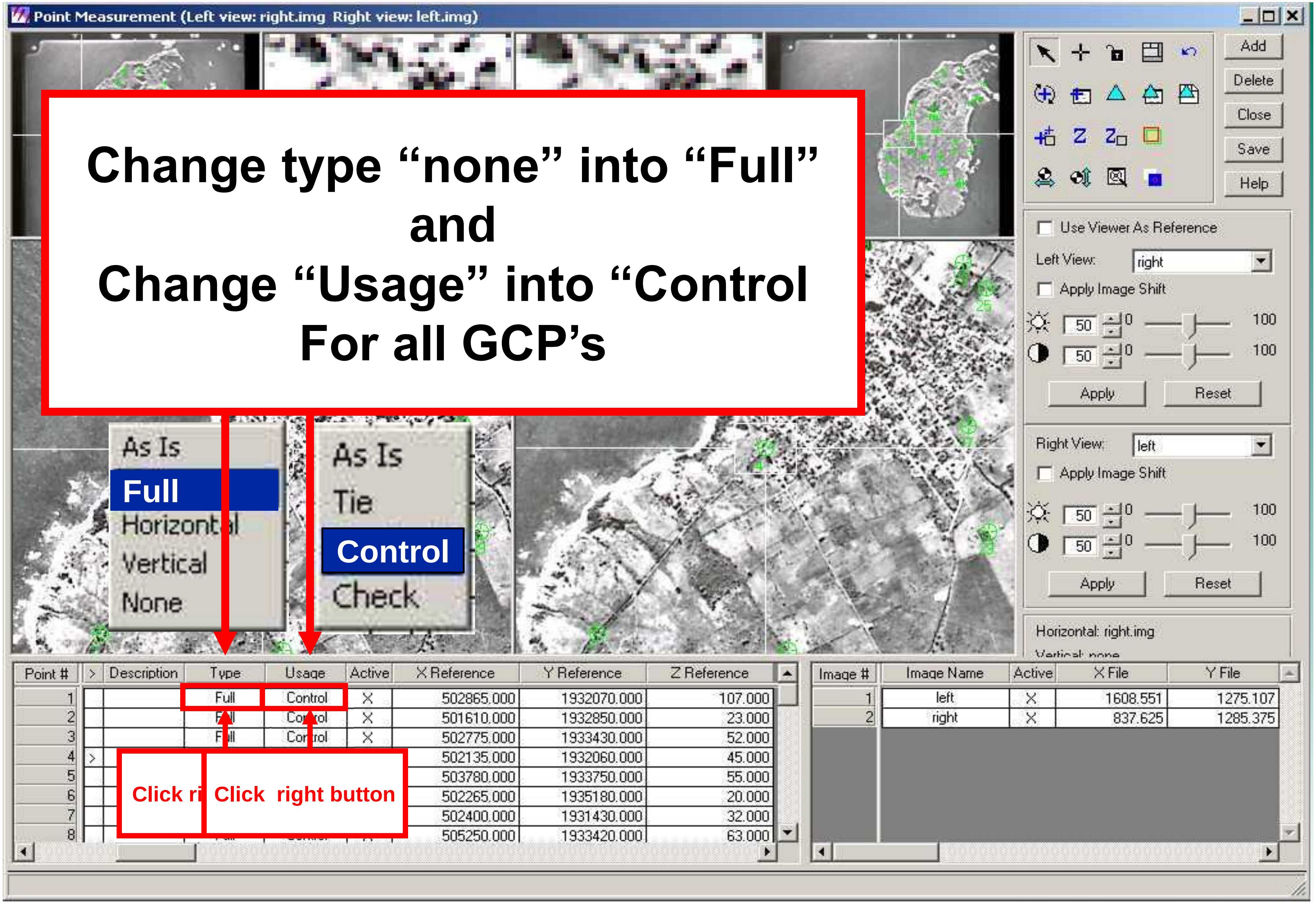
Horizontal: none

Vertical: none

Point #	>	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference
1			None	Tie	X	502865.000	1932070.000	107.000
2			None	Tie	X	501610.000	1932850.000	23.000
3			None	Tie	X	502775.000	1933430.000	52.000
4	>		None	Tie	X	502135.000	1932060.000	45.000

Image #	Image Name	Active	X File	Y File
1	left	X	2280.875	1477.375
2	right	X	1507.625	1481.625

Continue the same Procedure for the Remaining Ground Control Points according to map and Coordinate list



Change type “none” into “Full”
and
Change “Usage” into “Control
For all GCP’s

Click ri Click right button

☐ Use Viewer As Reference

Left View: right

☐ Apply Image Shift

50 0 100

50 0 100

Right View: left

☐ Apply Image Shift

50 0 100

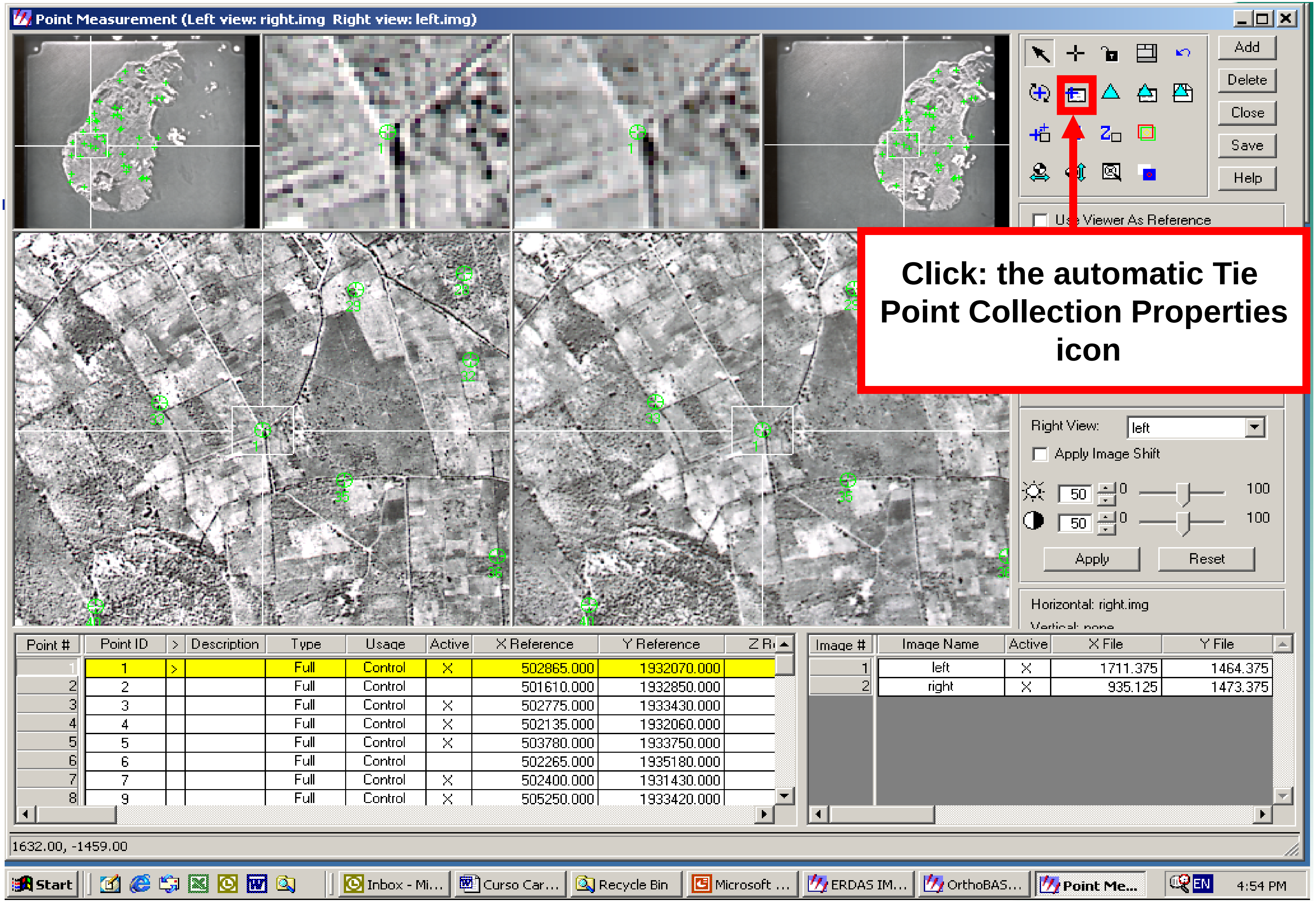
50 0 100

Horizontal: right.img

Vertical: none

Point #	>	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference
1			Full	Control	X	502865.000	1932070.000	107.000
2			Full	Control	X	501610.000	1932850.000	23.000
3			Full	Control	X	502775.000	1933430.000	52.000
4	>					502135.000	1932060.000	45.000
5						503780.000	1933750.000	55.000
6						502265.000	1935180.000	20.000
7						502400.000	1931430.000	32.000
8						505250.000	1933420.000	63.000

Image #	Image Name	Active	X File	Y File
1	left	X	1608.551	1275.107
2	right	X	837.625	1285.375



Point Measurement (Left view: right.img Right view: left.img)

Click: the automatic Tie Point Collection Properties icon

☐ Use Viewer As Reference

Right View: left

☐ Apply Image Shift

50 0 100

50 0 100

Apply Reset

Horizontal: right.img

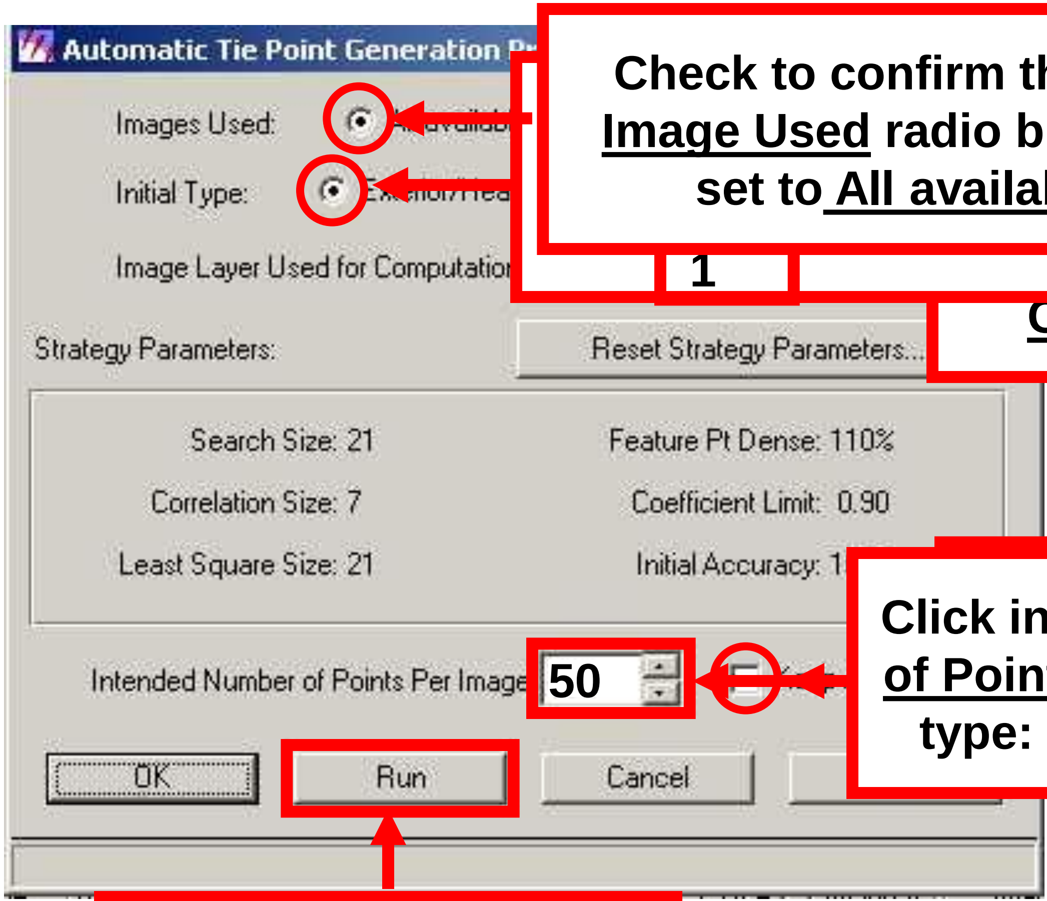
Vertical: none

Point #	Point ID	>	Description	Type	Usage	Active	X Reference	Y Reference	Z R
1	1	>		Full	Control	X	502865.000	1932070.000	
2	2			Full	Control		501610.000	1932850.000	
3	3			Full	Control	X	502775.000	1933430.000	
4	4			Full	Control	X	502135.000	1932060.000	
5	5			Full	Control	X	503780.000	1933750.000	
6	6			Full	Control		502265.000	1935180.000	
7	7			Full	Control	X	502400.000	1931430.000	
8	9			Full	Control	X	505250.000	1933420.000	

Image #	Image Name	Active	X File	Y File
1	left	X	1711.375	1464.375
2	right	X	935.125	1473.375

1632.00, -1459.00

ITC


Automatic Tie Point Generation P

Images Used:

Initial Type:

Image Layer Used for Computatio 1

Strategy Parameters:

Reset Strategy Parameters...

Search Size: 21

Feature Pt Dense: 110%

Correlation Size: 7

Coefficient Limit: 0.90

Least Square Size: 21

Initial Accuracy: 1

Intended Number of Points Per Image 50

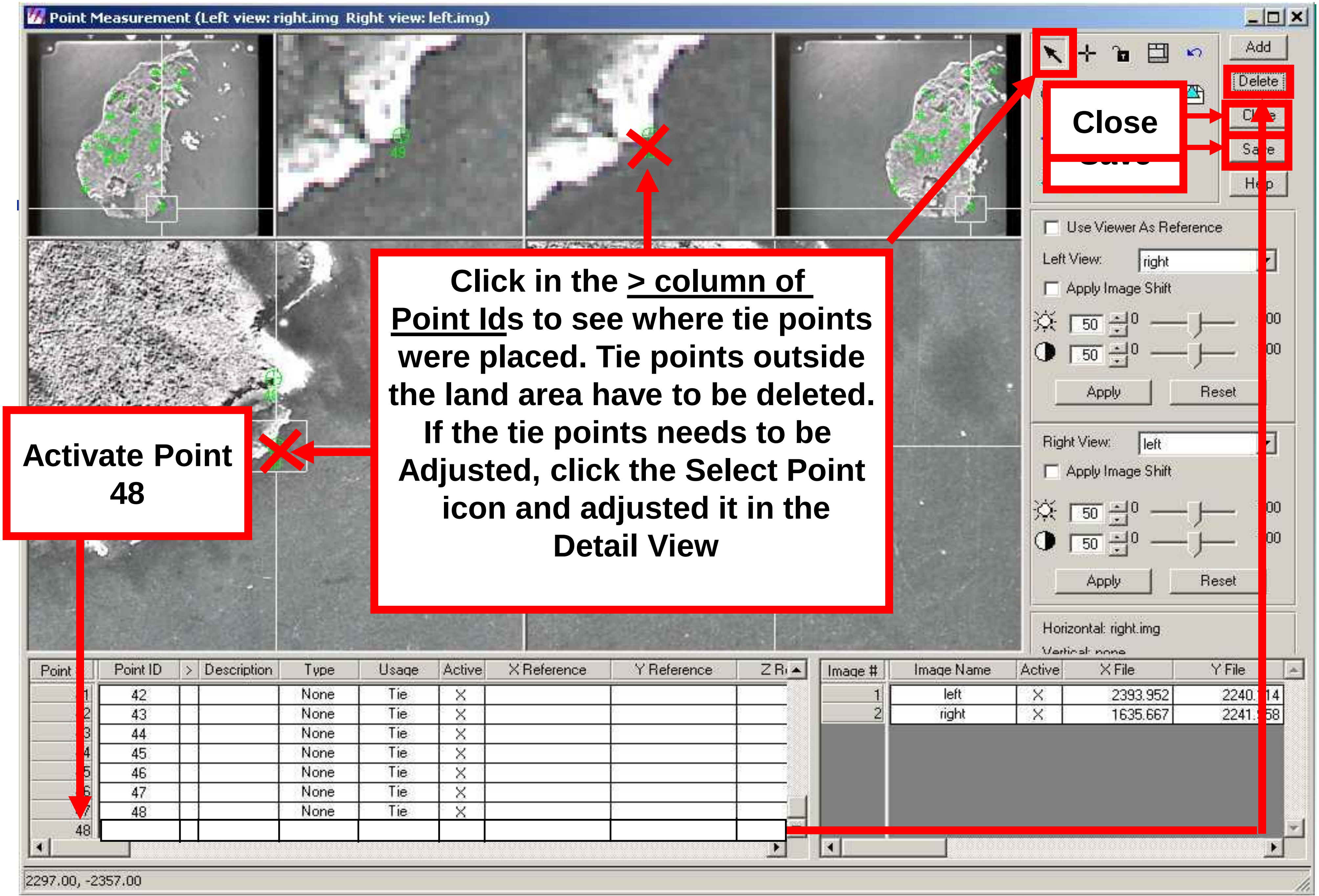
Check to confirm that the Image Used radio button is set to All available

nfirm that the
yer Used for
Computation is set to 1

Click in the Intended Number of Points Per Image field and type: 50, then press Enter

d)

Click the Run button



Click in the > column of Point Ids to see where tie points were placed. Tie points outside the land area have to be deleted. If the tie points needs to be Adjusted, click the Select Point icon and adjusted it in the Detail View

Activate Point 48

Close

Save

Point Measurement (Left view: right.img Right view: left.img)

☐ Use Viewer As Reference

Left View: right

☐ Apply Image Shift

Right View: left

☐ Apply Image Shift

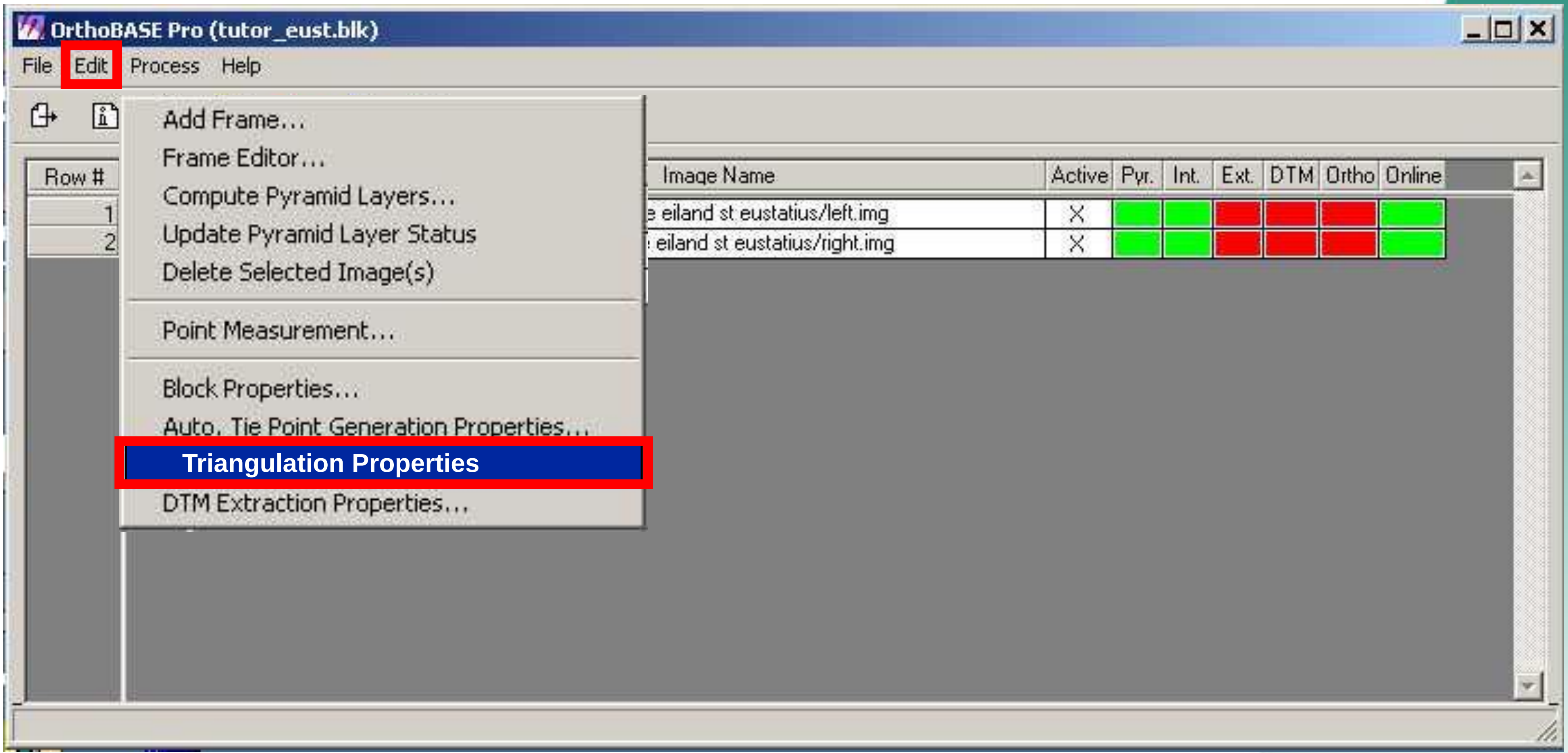
Horizontal: right.img

Vertical: none

Point #	Point ID	>	Description	Type	Usage	Active	X Reference	Y Reference	Z R
41	42			None	Tie	X			
42	43			None	Tie	X			
43	44			None	Tie	X			
44	45			None	Tie	X			
45	46			None	Tie	X			
46	47			None	Tie	X			
47	48			None	Tie	X			
48									

Image #	Image Name	Active	X File	Y File
1	left	X	2393.952	2240.[illegible]14
2	right	X	1635.667	2241.[illegible]58

2297.00, -2357.00


OrthoBASE Pro (tutor_eust.blk)
File
Edit
Process
Help
Add Frame...
Frame Editor...
Compute Pyramid Layers...
Update Pyramid Layer Status
Delete Selected Image(s)
Point Measurement...
Block Properties...
Auto. Tie Point Generation Properties...
Triangulation Properties
DTM Extraction Properties...

Row #	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	e eiland st eustatius/left.img	X	🟩	🟩	🟥	🟥	🟥	🟩
2	: eiland st eustatius/right.img	X	🟩	🟩	🟥	🟥	🟥	🟩

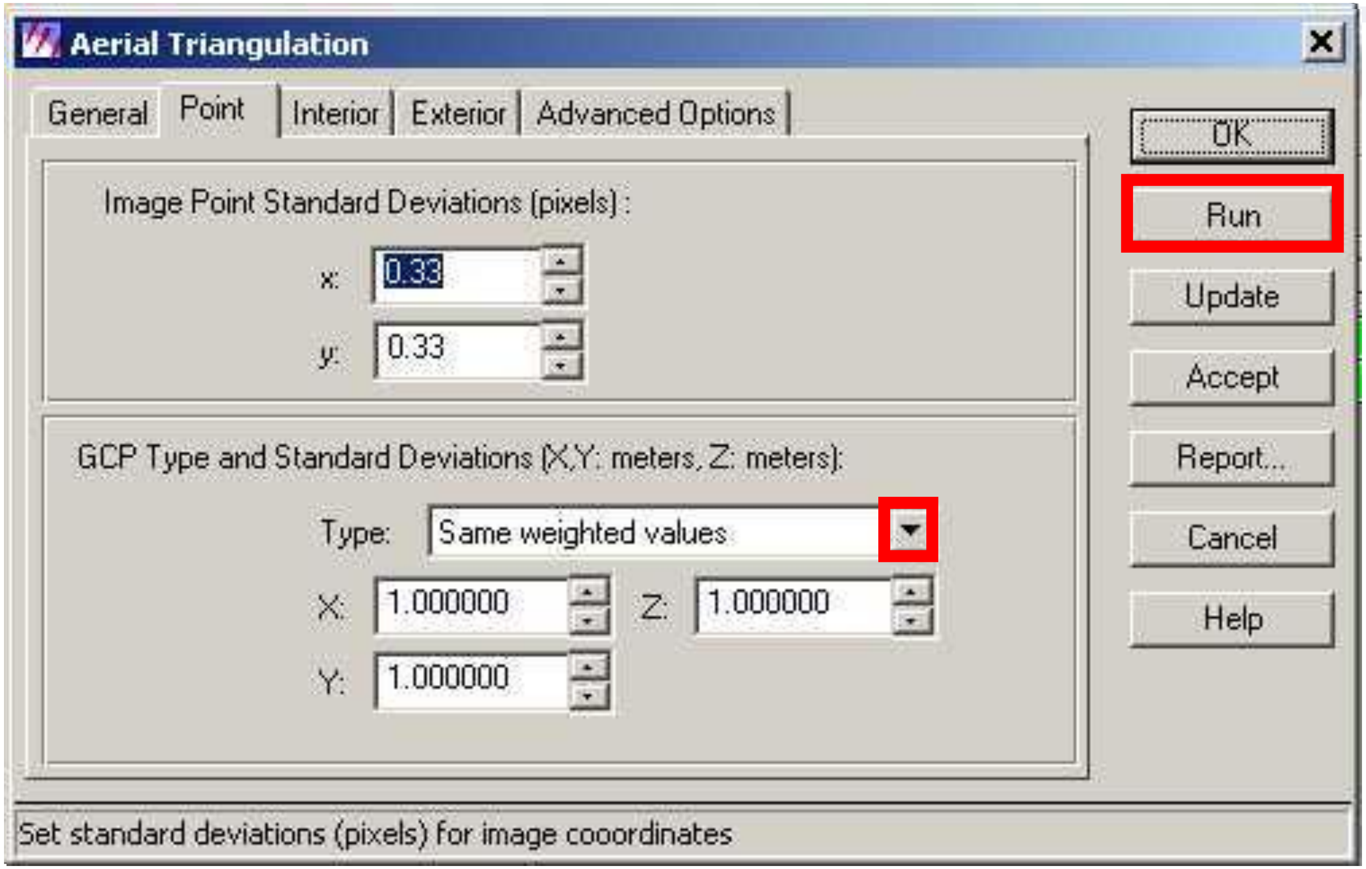


Image Point Standard Deviations (pixels) :

x: 0.33

y: 0.33

GCP Type and Standard Deviations (X,Y: meters, Z: meters):

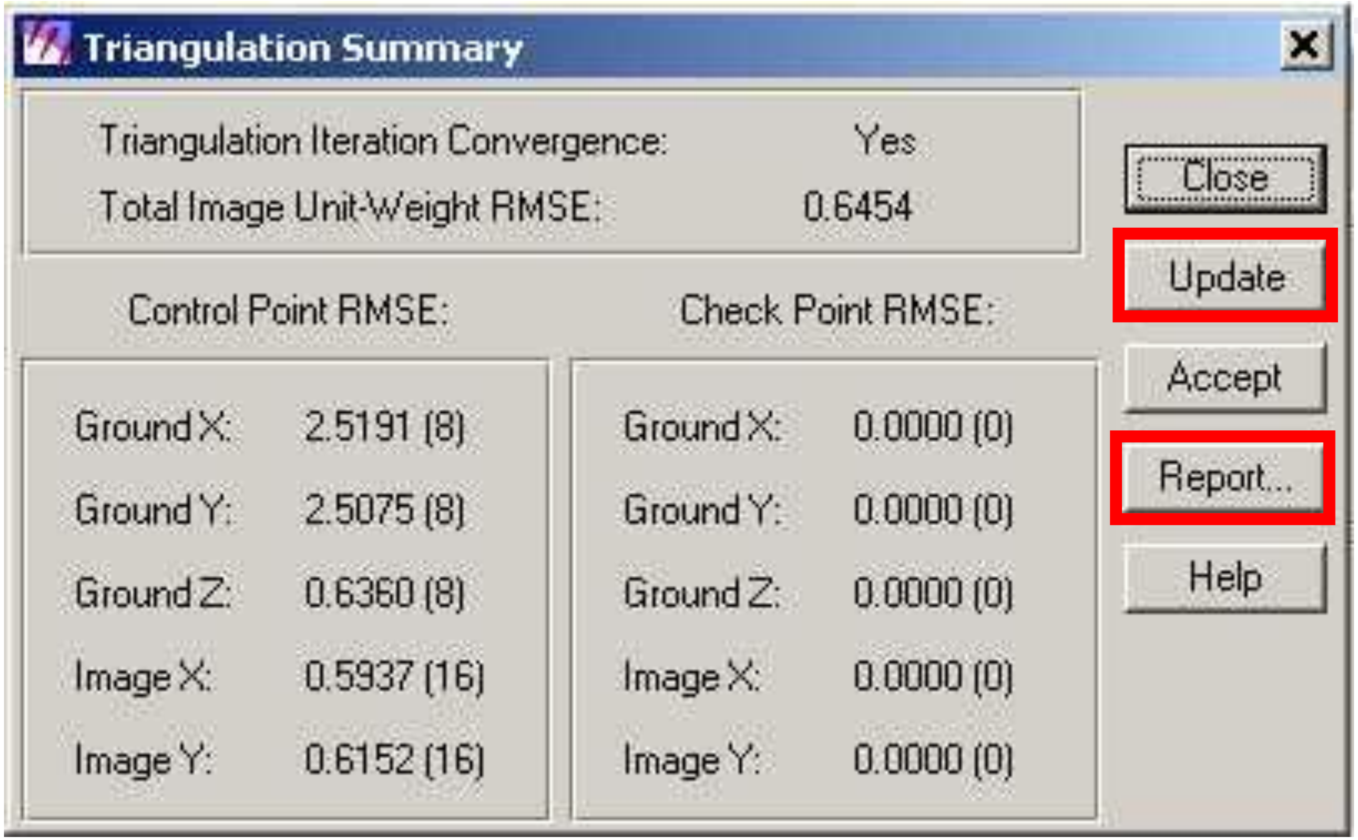
Type: Same weighted values

X: 1.000000

Z: 1.000000

Y: 1.000000

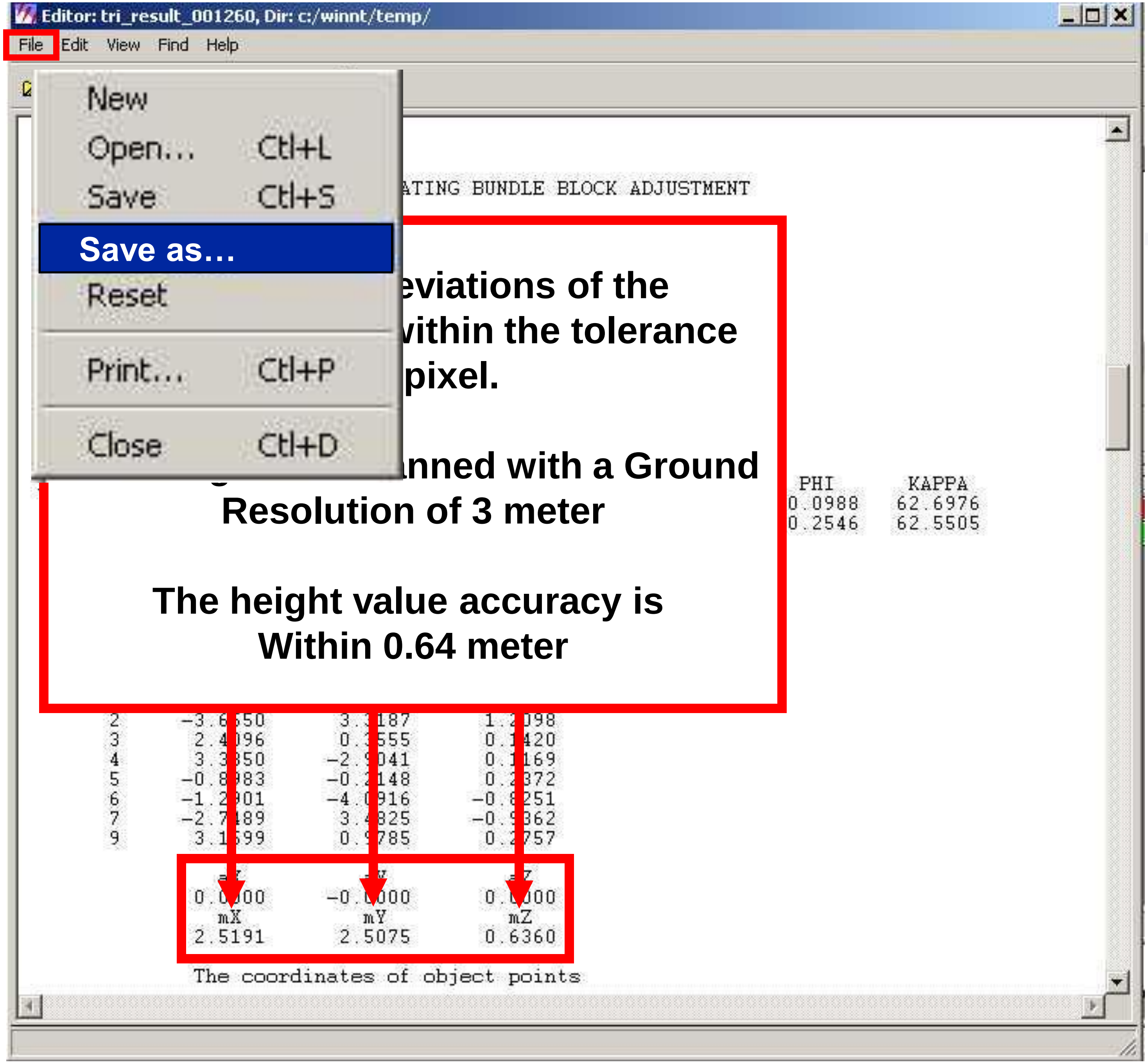
Set standard deviations (pixels) for image coordinates



Triangulation Iteration Convergence: Yes

Total Image Unit-Weight RMSE: 0.6454

Control Point RMSE:		Check Point RMSE:	
Ground X:	2.5191 (8)	Ground X:	0.0000 (0)
Ground Y:	2.5075 (8)	Ground Y:	0.0000 (0)
Ground Z:	0.6360 (8)	Ground Z:	0.0000 (0)
Image X:	0.5937 (16)	Image X:	0.0000 (0)
Image Y:	0.6152 (16)	Image Y:	0.0000 (0)

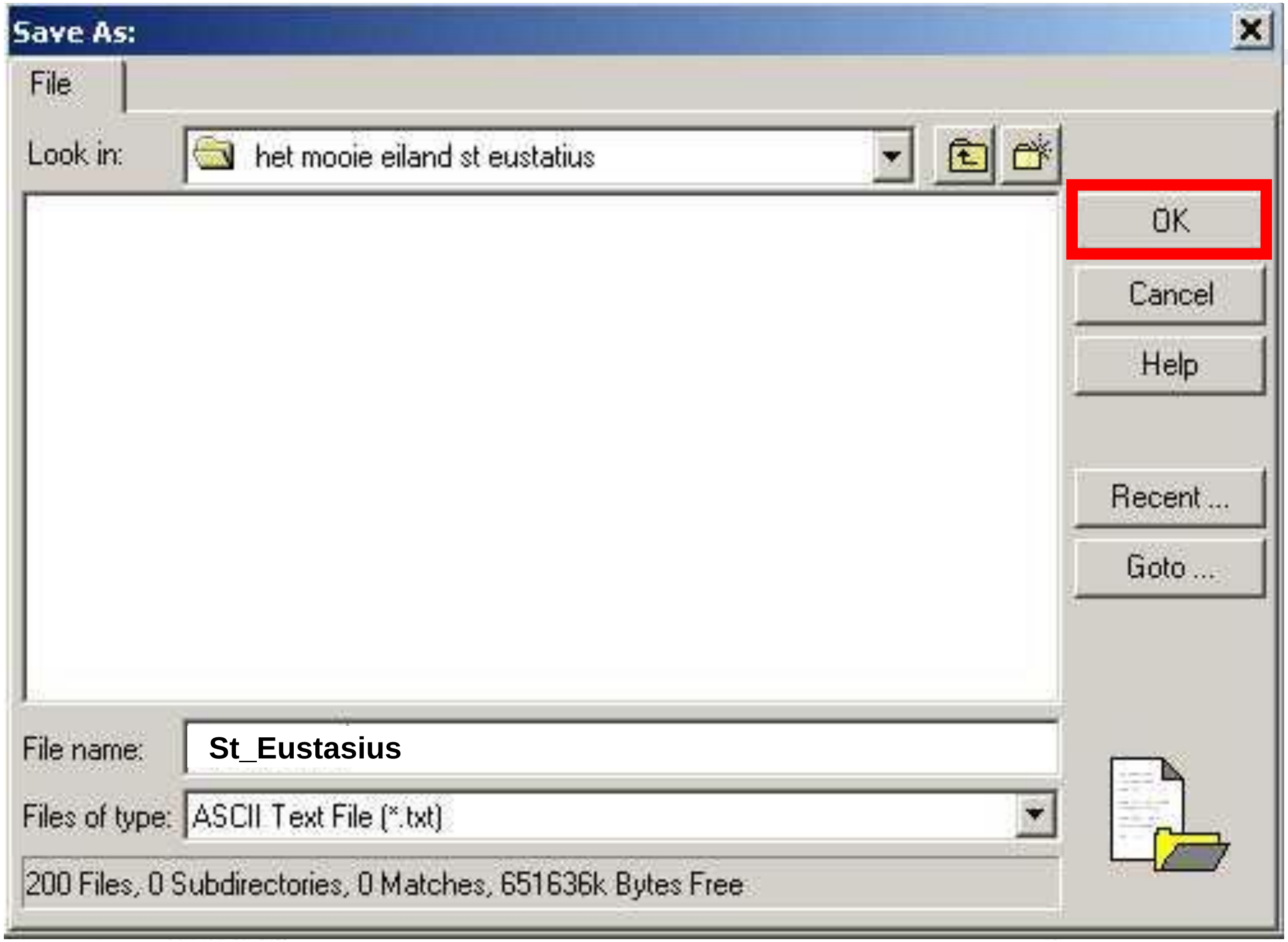


```
ATING BUNDLE BLOCK ADJUSTMENT

                                   PHI        KAPPA
                                  0.0988     62.6976
                                  0.2546     62.5505

  2      -3.6 50      3. 187      1. 098
  3       2.4 96      0. 555      0. 420
  4       3.3 50     -2. 041      0. 169
  5      -0.8 83     -0. 148      0. 372
  6      -1.2 01     -4.0 16     -0. 251
  7      -2.7 89      3.4 25     -0. 362
  9       3.1 99      0. 785      0. 757

          0. 00      -0. 000      0. 000
           mX          mY          mZ
          2.5191      2.5075      0.6360
  The coordinates of object points
```

eviations of the
within the tolerance
pixel.

nned with a Ground
Resolution of 3 meter

The height value accuracy is
Within 0.64 meter



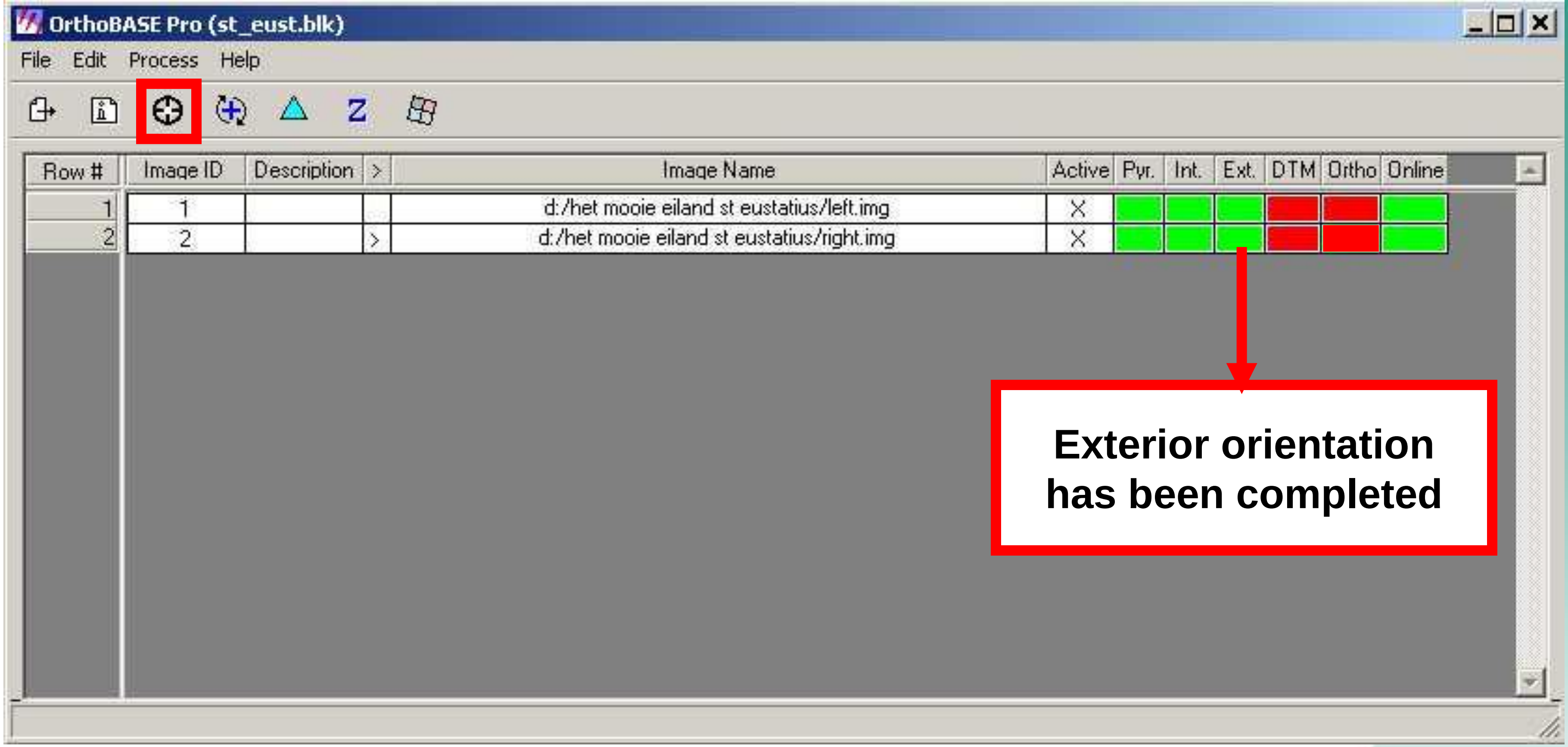
Save As:

Look in: het mooie eiland st eustatius

File name: **St_Eustasius**

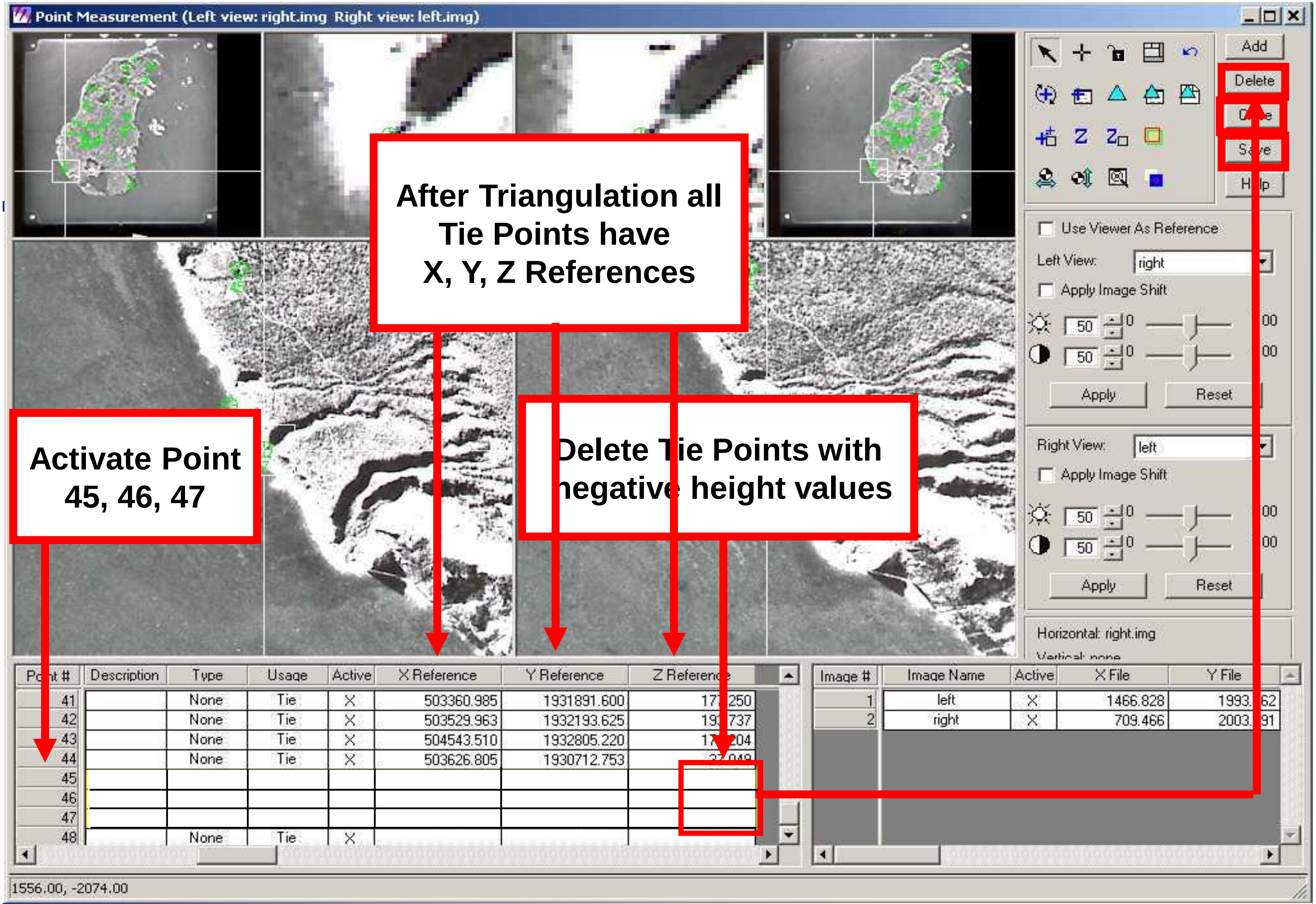
Files of type: ASCII Text File (*.txt)

200 Files, 0 Subdirectories, 0 Matches, 651636k Bytes Free



Row #	Image ID	Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1			d:/het mooie eiland st eustatius/left.img	X	🟩	🟩	🟩	🟥	🟥	🟩
2	2		>	d:/het mooie eiland st eustatius/right.img	X	🟩	🟩	🟩	🟥	🟥	🟩

Exterior orientation has been completed



Point Measurement (Left view: right.img Right view: left.img)

☐ Use Viewer As Reference

Left View: right

☐ Apply Image Shift

Right View: left

☐ Apply Image Shift

Horizontal: right.img

Vertical: none

After Triangulation all Tie Points have X, Y, Z References

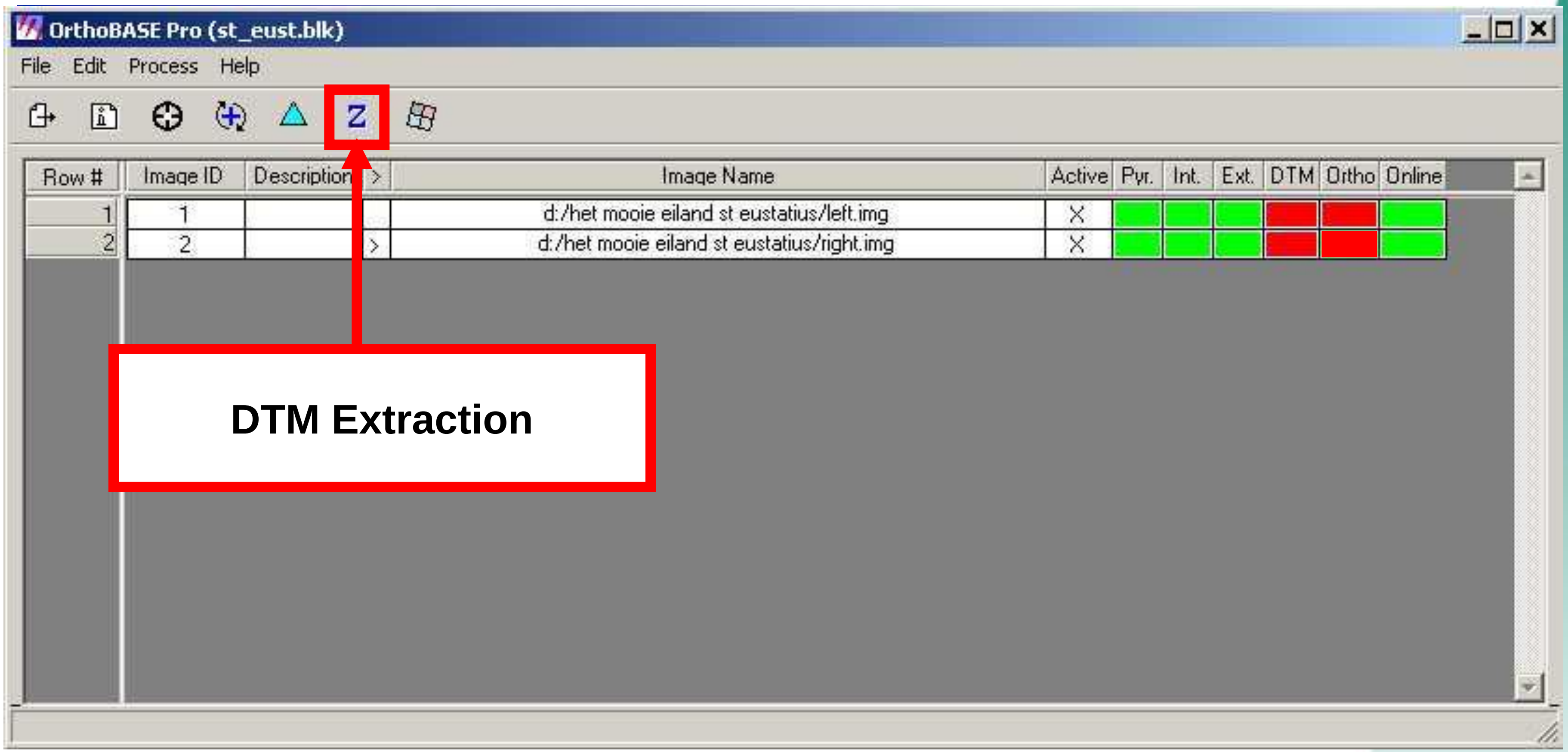
Activate Point 45, 46, 47

Delete Tie Points with negative height values

Point #	Description	Type	Usage	Active	X Reference	Y Reference	Z Reference
41		None	Tie	X	503360.985	1931891.600	17[illegible]250
42		None	Tie	X	503529.963	1932193.625	19[illegible]737
43		None	Tie	X	504543.510	1932805.220	17[illegible]204
44		None	Tie	X	503626.805	1930712.753	[illegible]
45							
46							
47							
48		None	Tie	X			

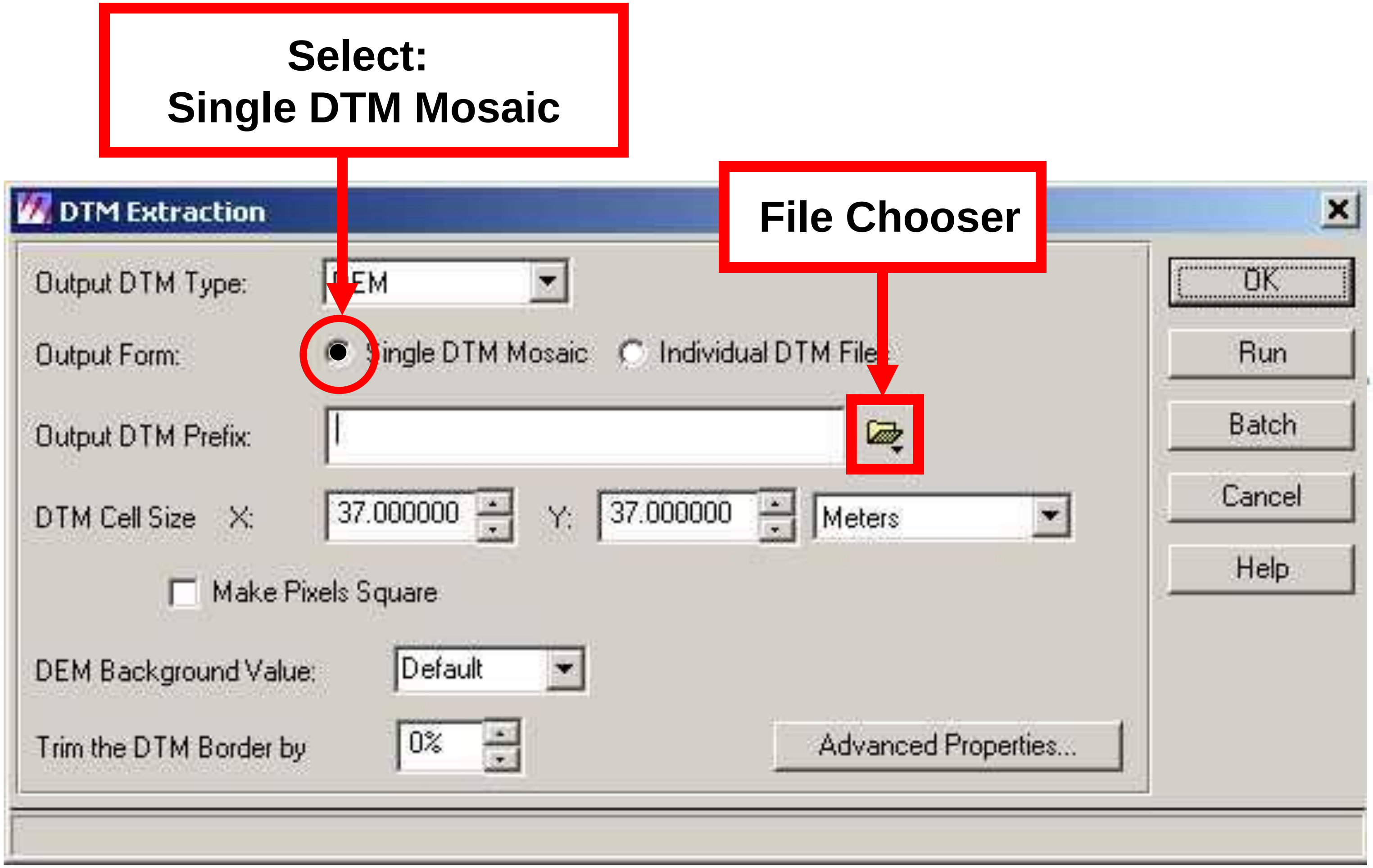
Image #	Image Name	Active	X File	Y File
1	left	X	1466.828	1993.[illegible]62
2	right	X	709.466	2003.[illegible]91

1556.00, -2074.00



Row #	Image ID	Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1			d:/het mooie eiland st eustatius/left.img	X	🟩	🟩	🟩	🟥	🟥	🟩
2	2		>	d:/het mooie eiland st eustatius/right.img	X	🟩	🟩	🟩	🟥	🟥	🟩

DTM Extraction



Select:
Single DTM Mosaic

File Chooser

DTM Extraction

Output DTM Type: DEM

Output Form: ● Single DTM Mosaic ○ Individual DTM Files

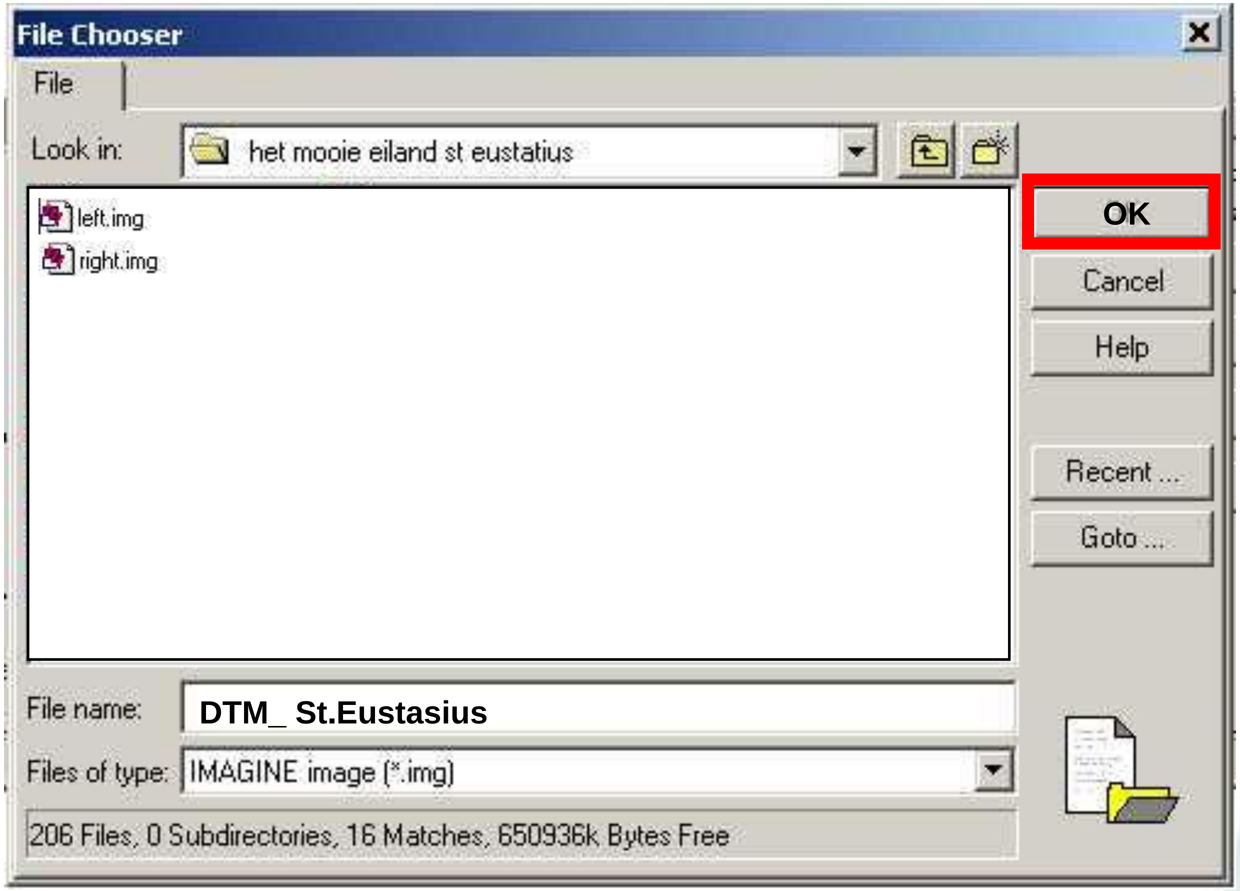
Output DTM Prefix:

DTM Cell Size X: 37.000000 Y: 37.000000 Meters

☐ Make Pixels Square

DEM Background Value: Default

Trim the DTM Border by 0%



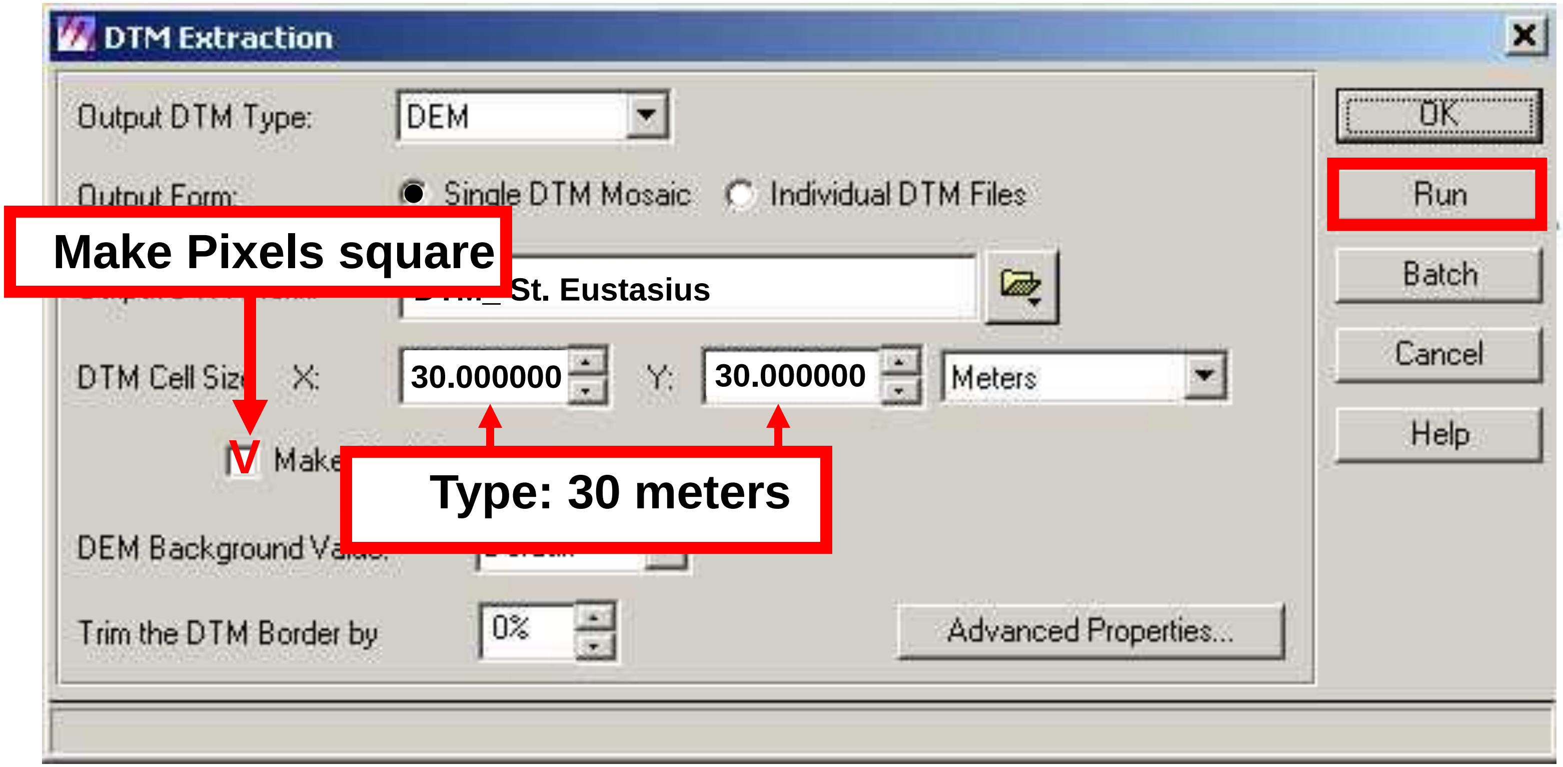
Look in: het mooie eiland st eustatius

left.img
right.img

File name: **DTM_ St.Eustasius**

Files of type: IMAGINE image (*.img)

206 Files, 0 Subdirectories, 16 Matches, 650936k Bytes Free



Output DTM Type: DEM

Output Form: ● Single DTM Mosaic ○ Individual DTM Files

St. Eustasius

DTM Cell Siz X: 30.000000 Y: 30.000000 Meters

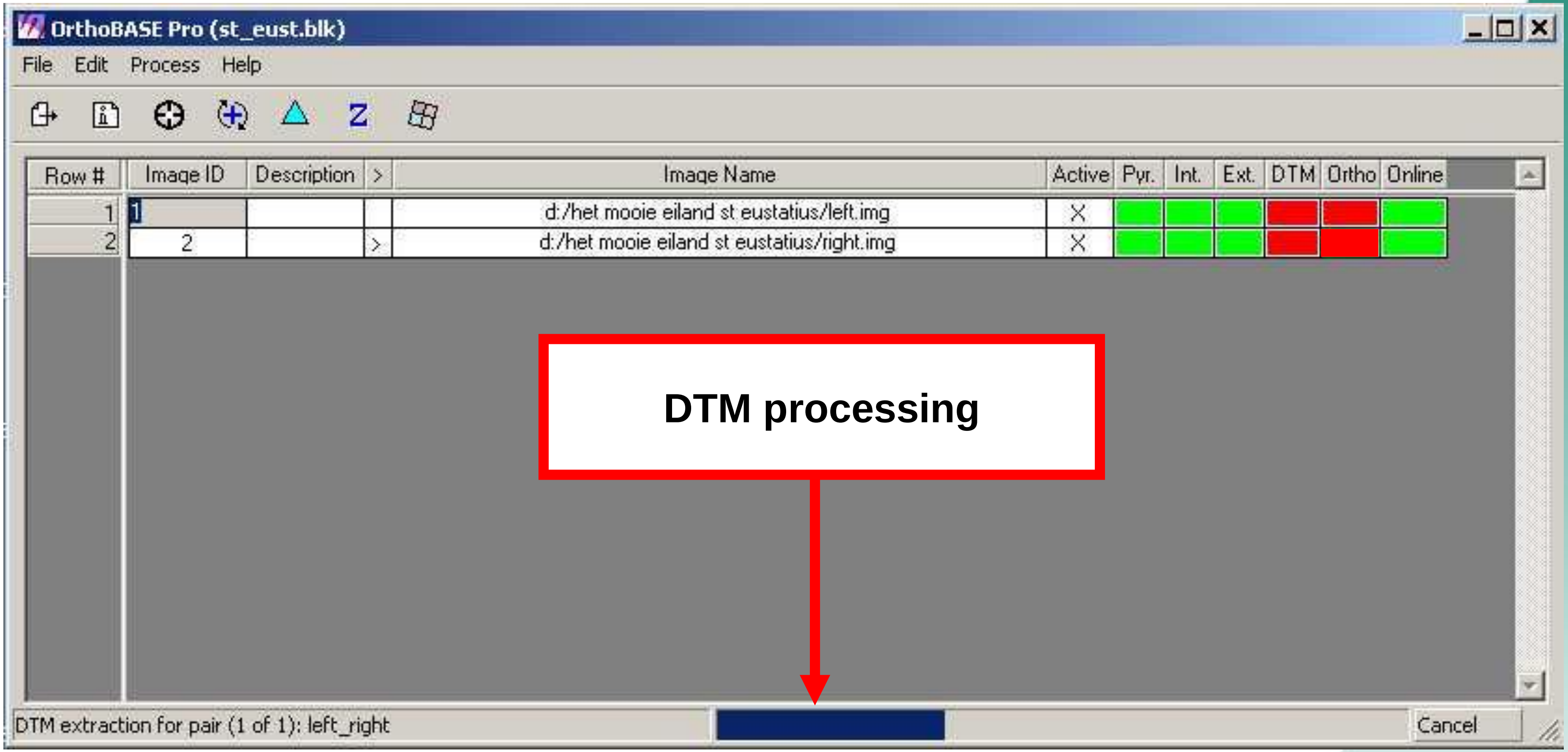
☑ Make

DEM Background Va

Trim the DTM Border by 0%

Make Pixels square

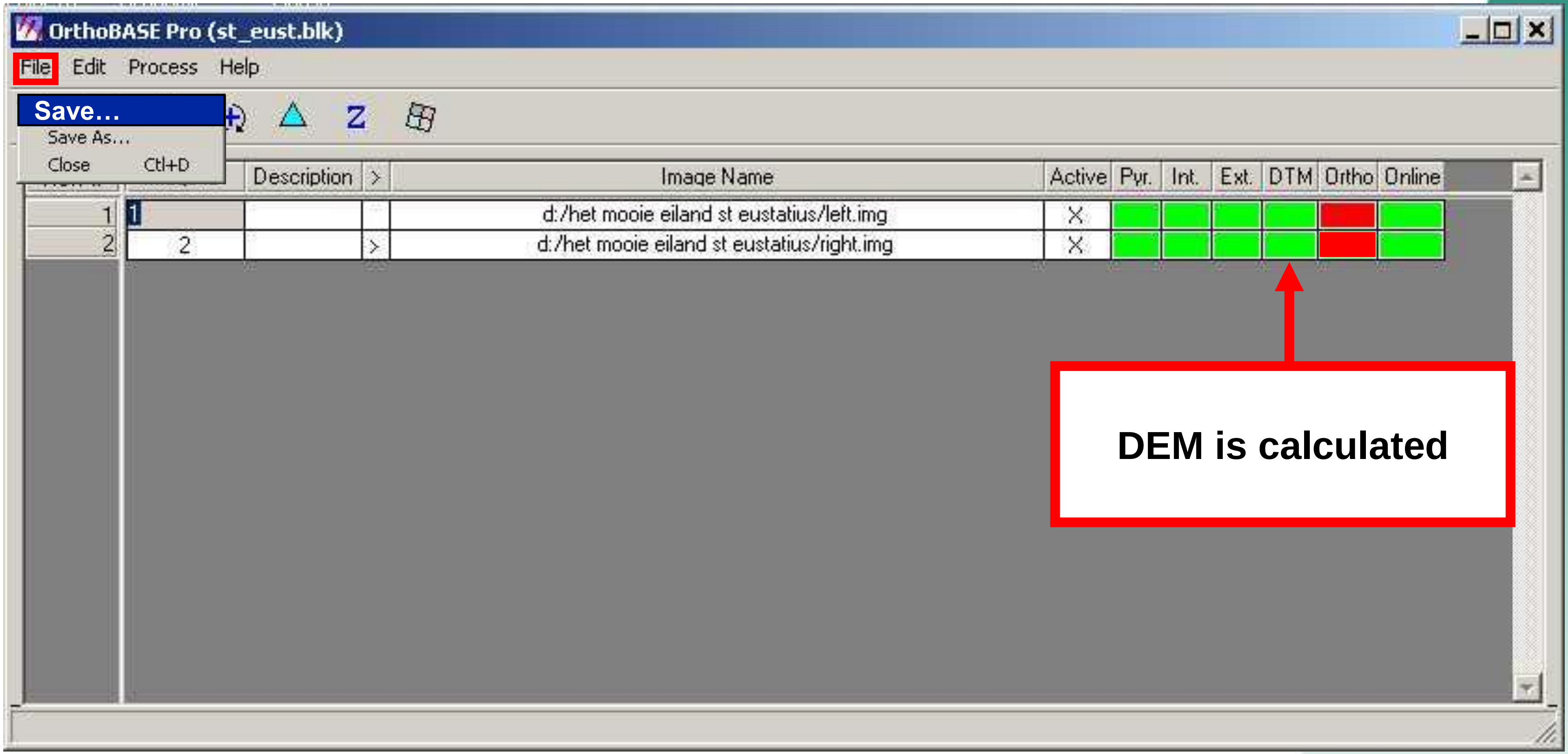
Type: 30 meters



Row #	Image ID	Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1			d:/het mooie eiland st eustatius/left.img	X	🟩	🟩	🟩	🟥	🟥	🟩
2	2		>	d:/het mooie eiland st eustatius/right.img	X	🟩	🟩	🟩	🟥	🟥	🟩

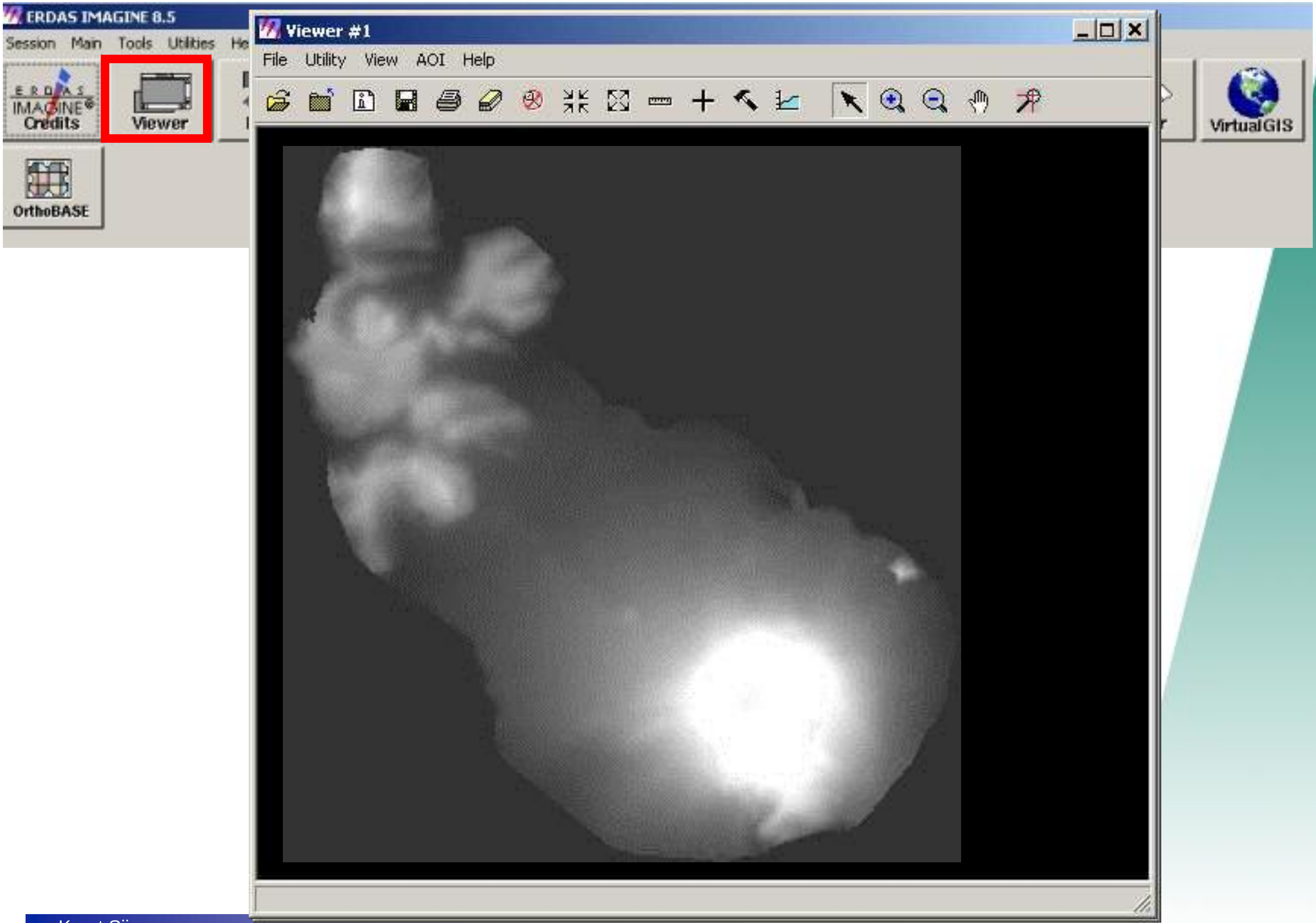
DTM extraction for pair (1 of 1): left_right

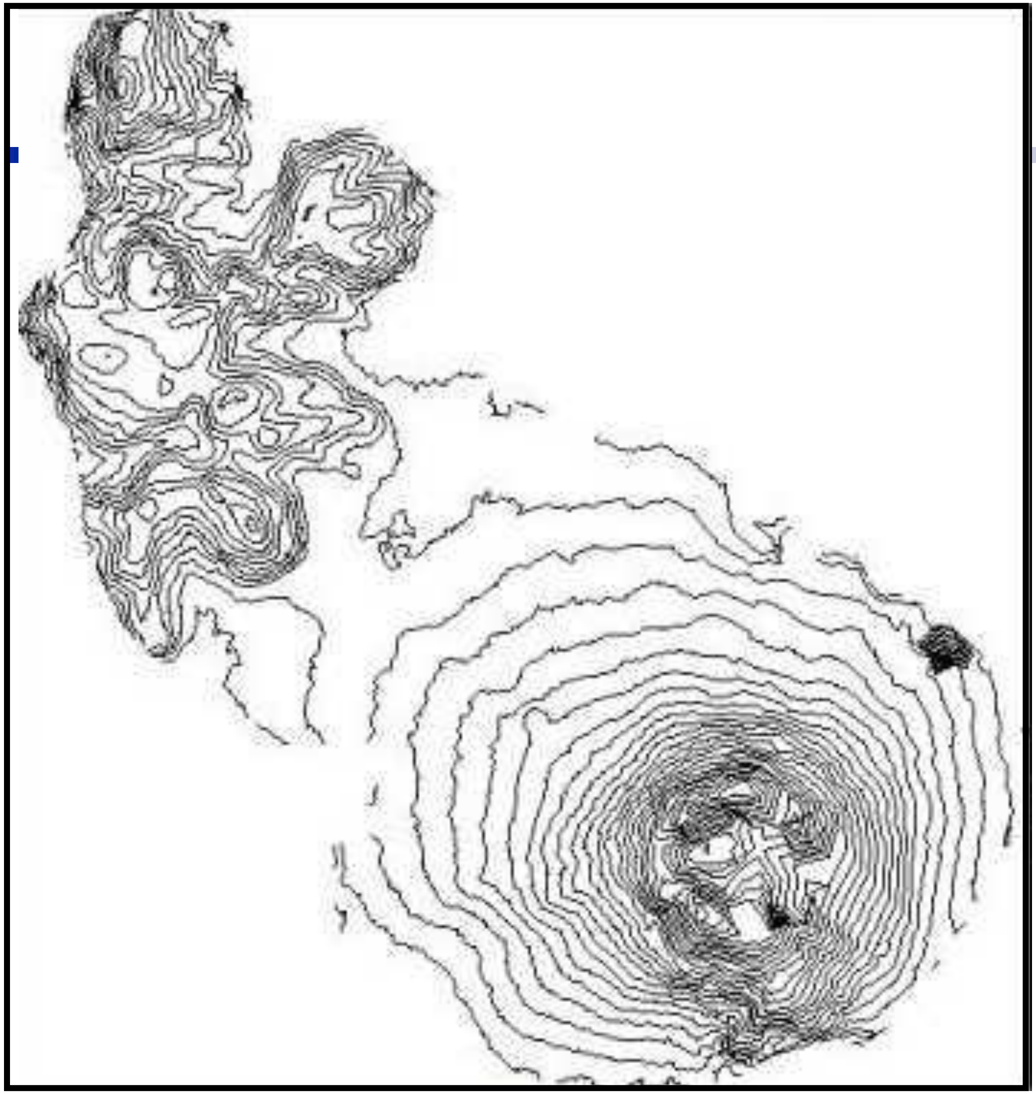
DTM processing



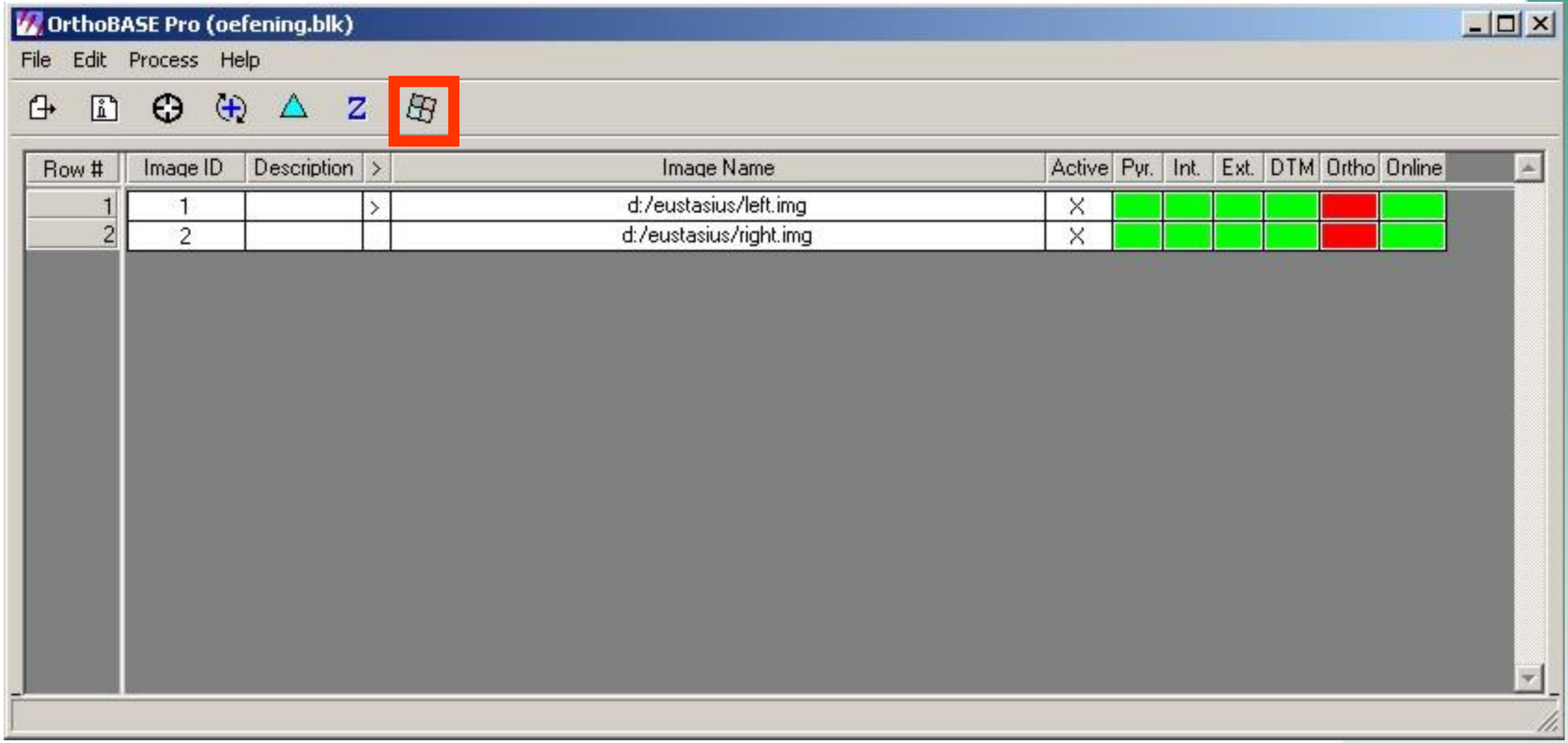
		Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1			d:/het mooie eiland st eustatius/left.img	X	🟩	🟩	🟩	🟩	🟥	🟩
2	2		>	d:/het mooie eiland st eustatius/right.img	X	🟩	🟩	🟩	🟩	🟥	🟩

DEM is calculated


ERDAS IMAGINE 8.5
Session
Main
Tools
Utilities
He
ERDAS IMAGINE® Credits
Viewer
OrthoBASE
VirtualGIS
Viewer #1
File
Utility
View
AOI
Help



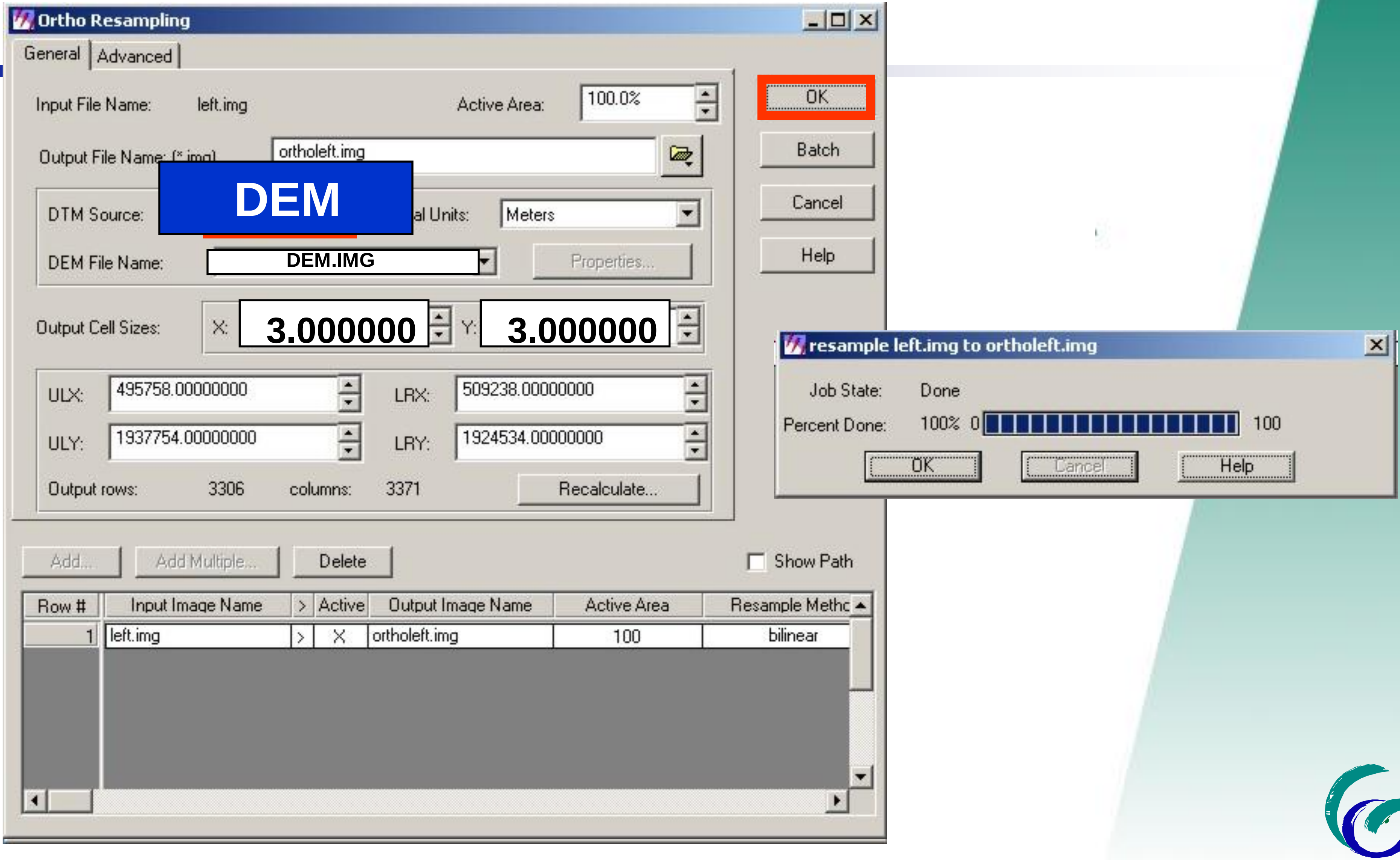
Orthophoto generating



OrthoBASE Pro (oefening.blk)

Row #	Image ID	Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1		>	d:/eustasius/left.img	X	🟩	🟩	🟩	🟩	🟥	🟩
2	2			d:/eustasius/right.img	X	🟩	🟩	🟩	🟩	🟥	🟩

Orthophoto Resampling



Ortho Resampling

General | Advanced

Input File Name: left.img

Active Area: 100.0%

Output File Name: (*.img) ortholeft.img

DTM Source: DEM

Vertical Units: Meters

DEM File Name: DEM.IMG

Output Cell Sizes: X: 3.000000 Y: 3.000000

ULX: 495758.00000000

LRX: 509238.00000000

ULY: 1937754.00000000

LRY: 1924534.00000000

Output rows: 3306 columns: 3371

☐ Show Path

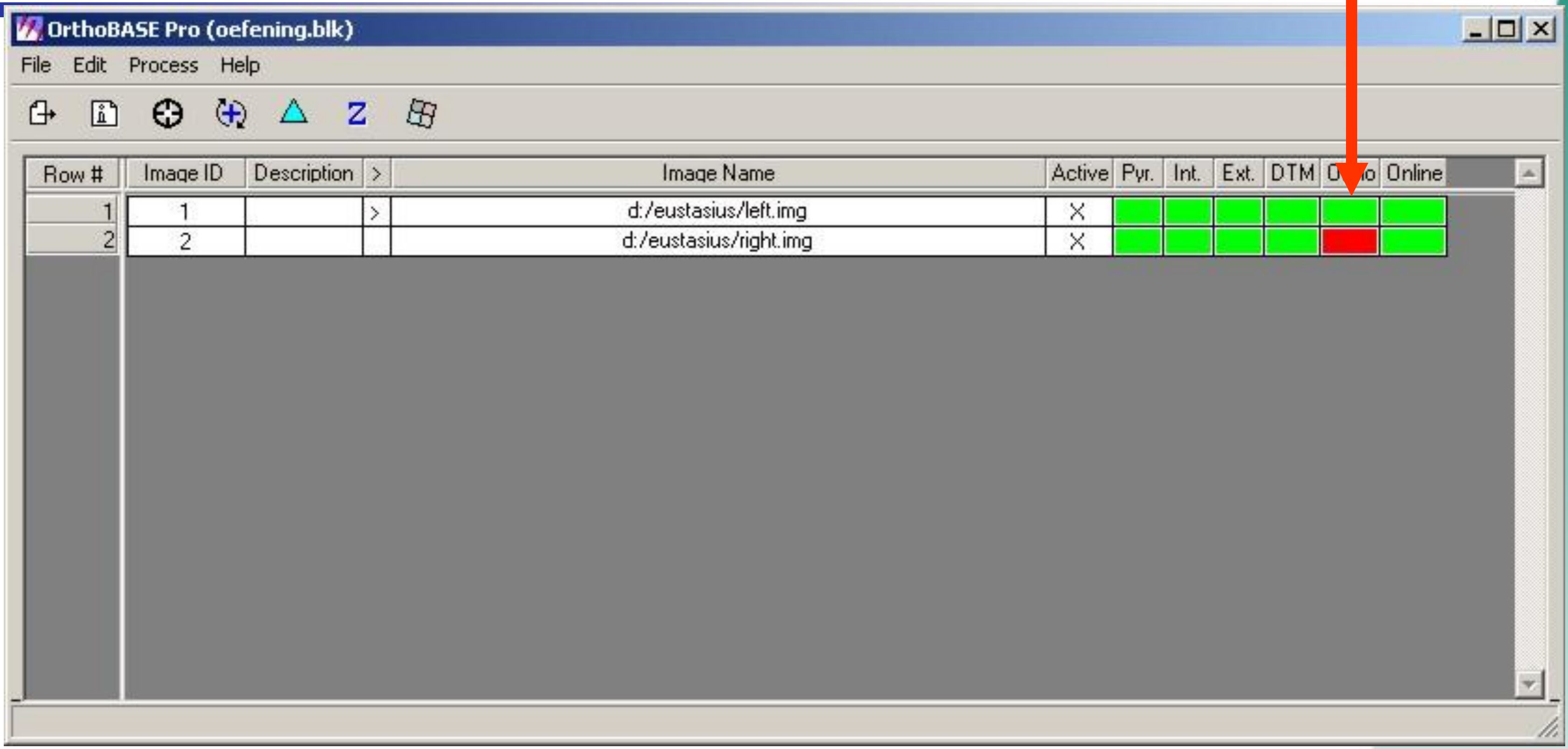
Row #	Input Image Name	>	Active	Output Image Name	Active Area	Resample Metho
1	left.img	>	X	ortholeft.img	100	bilinear

resample left.img to ortholeft.img

Job State: Done

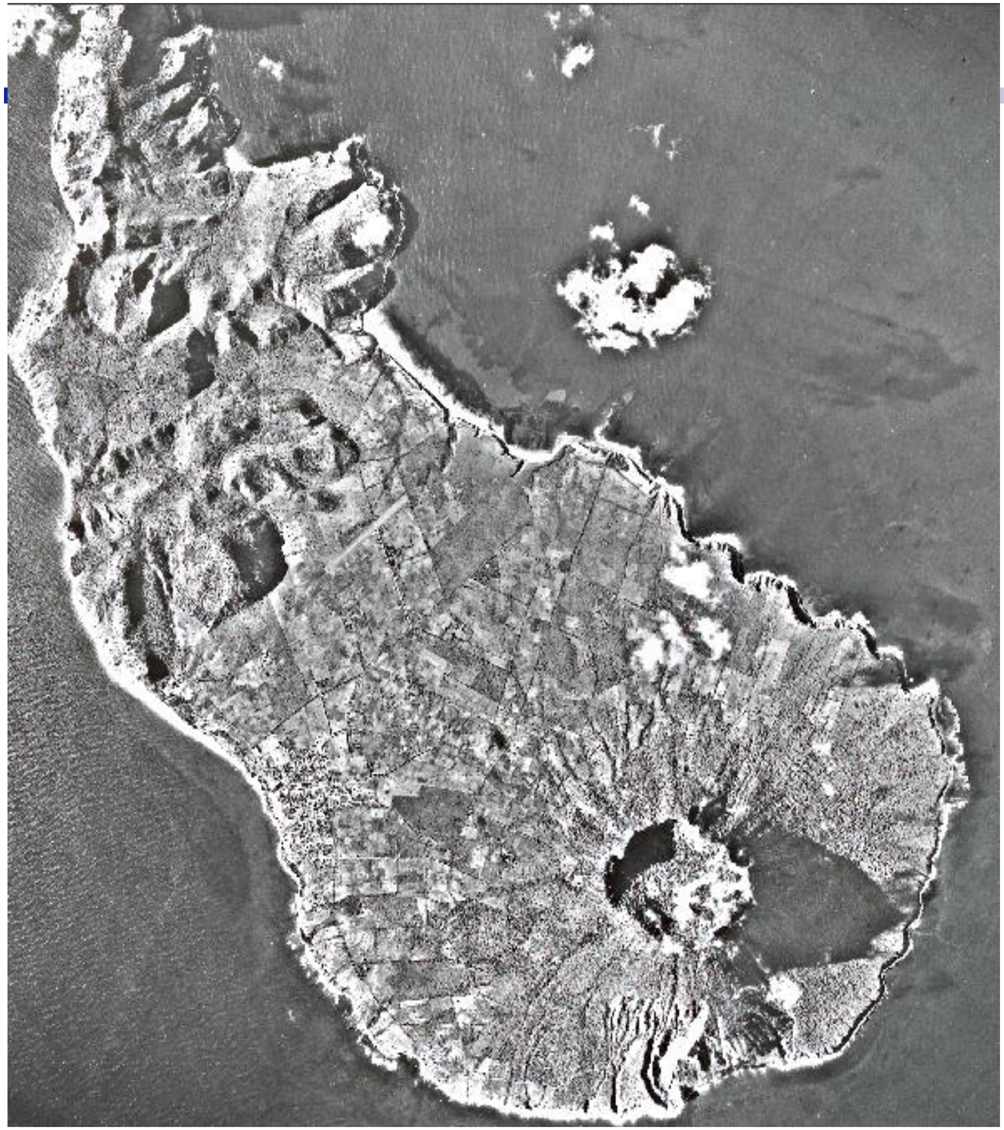
Percent Done: 100%

Orthophoto generated

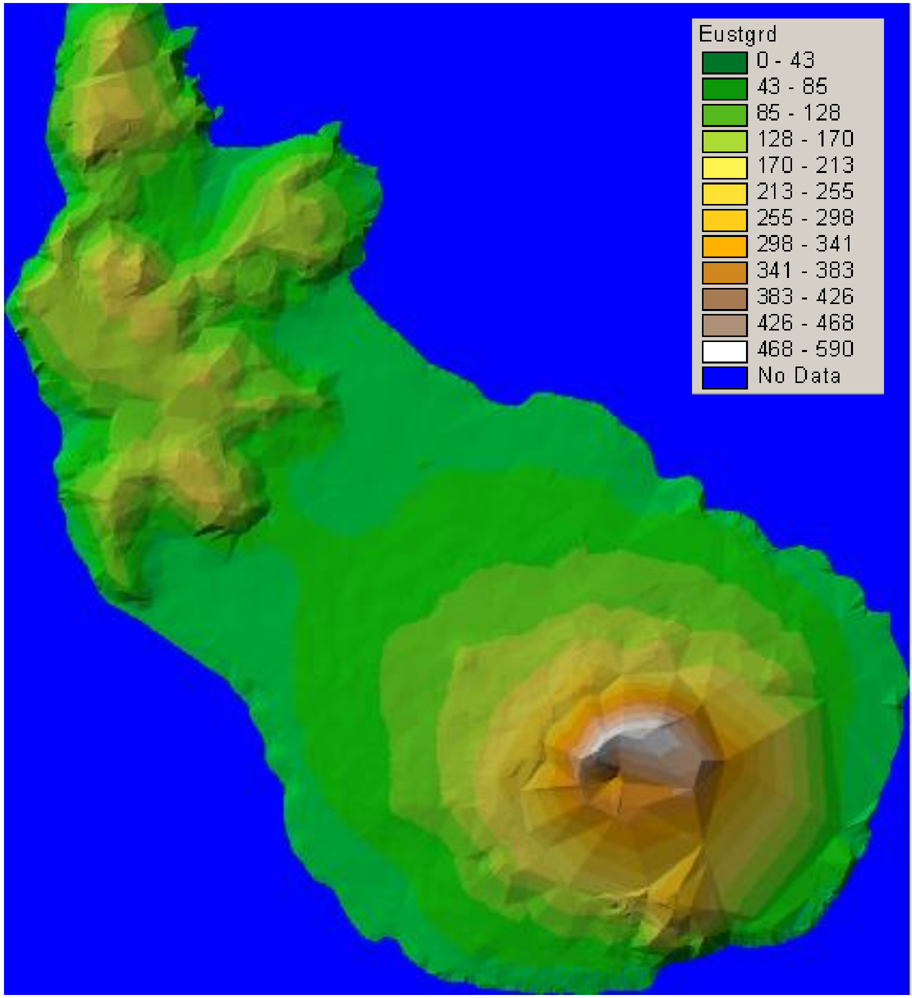


Row #	Image ID	Description	>	Image Name	Active	Pyr.	Int.	Ext.	DTM	Ortho	Online
1	1		>	d:/eustasius/left.img	X	🟩	🟩	🟩	🟩	🟩	🟩
2	2			d:/eustasius/right.img	X	🟩	🟩	🟩	🟩	🟥	🟩

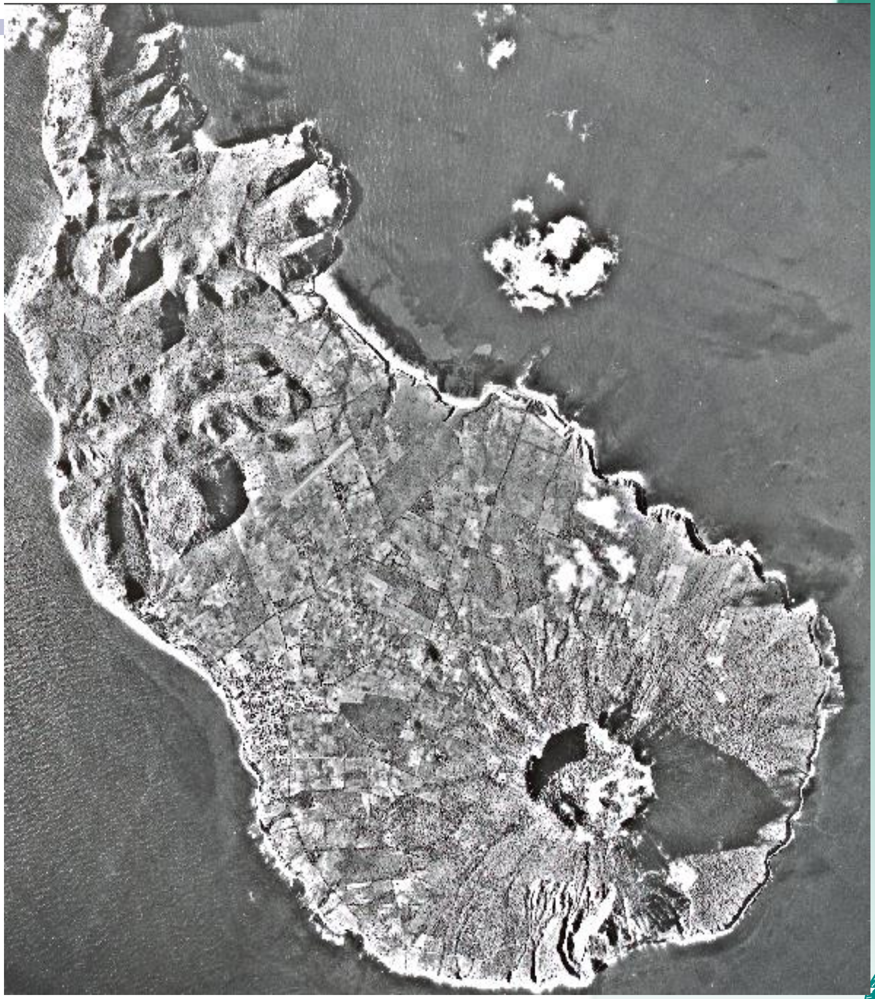
Orthophoto



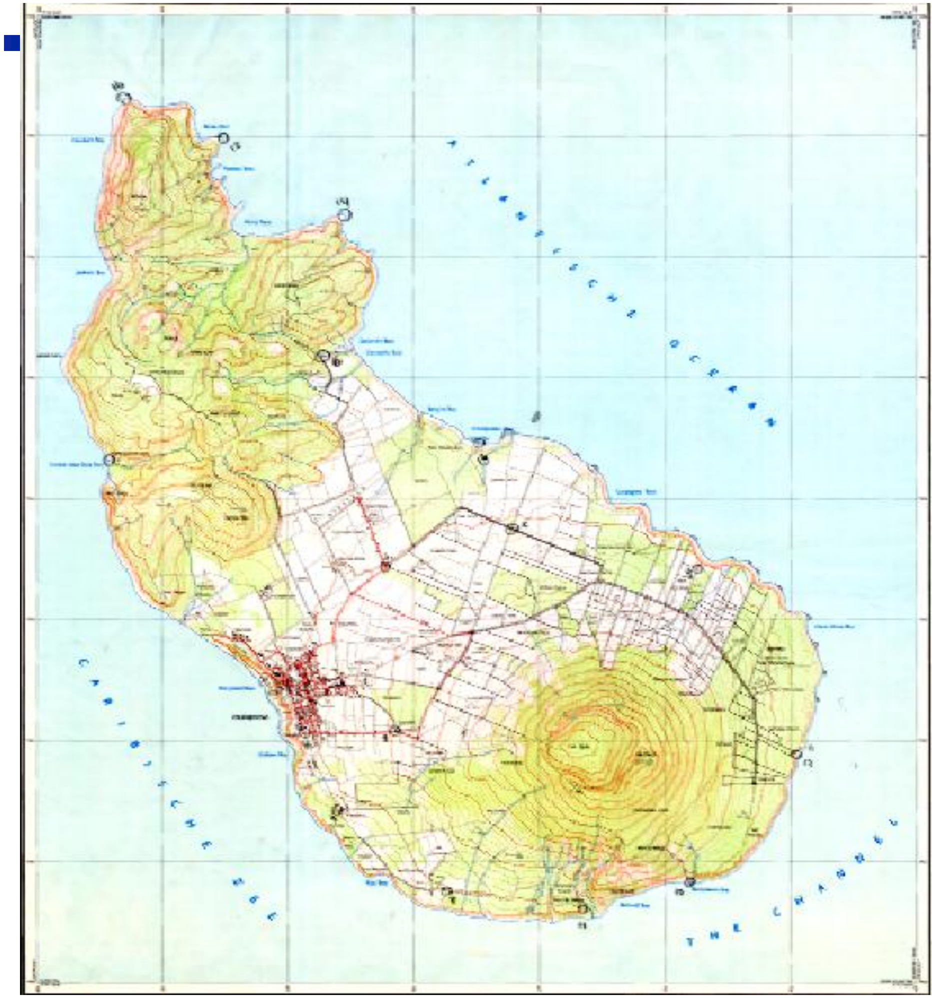
DEM



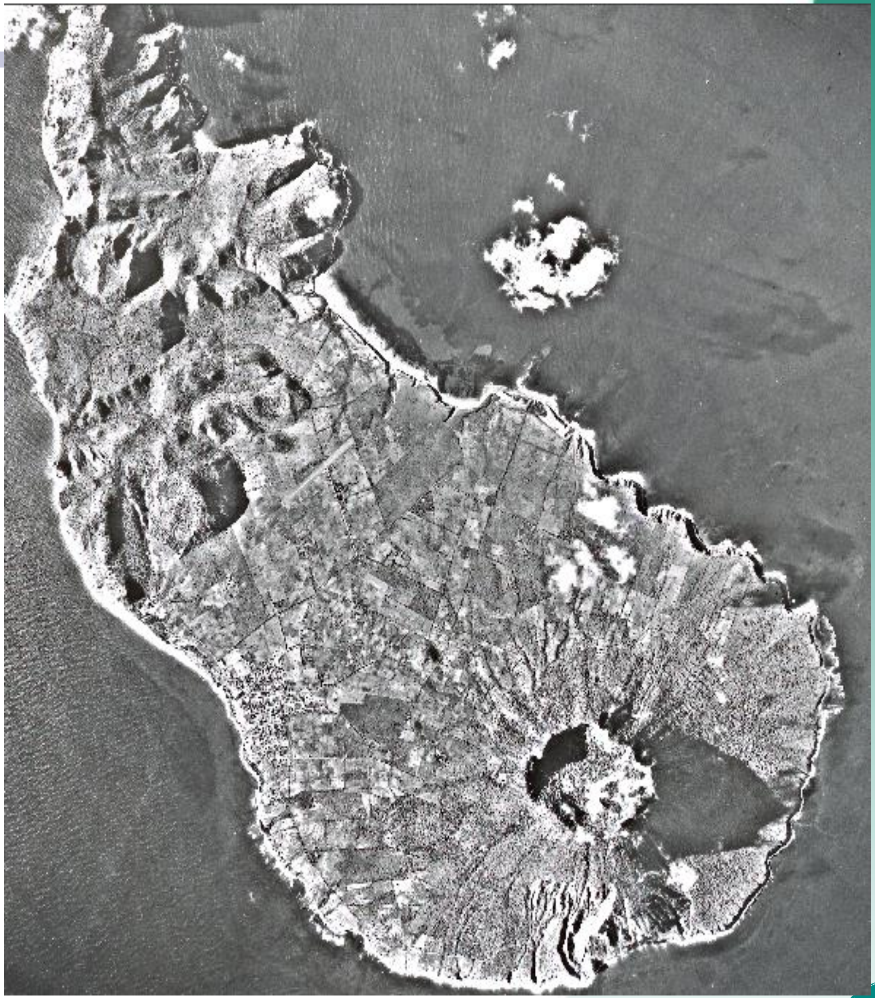
Orthophoto

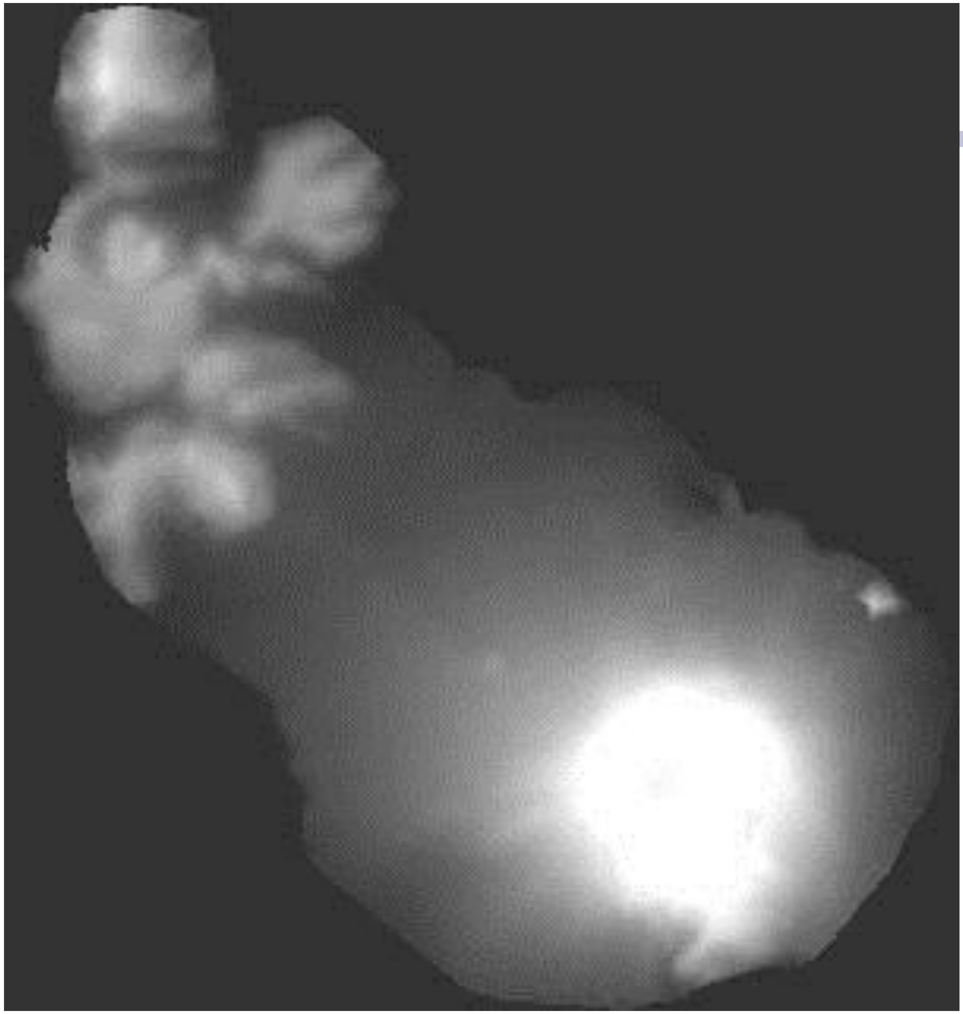


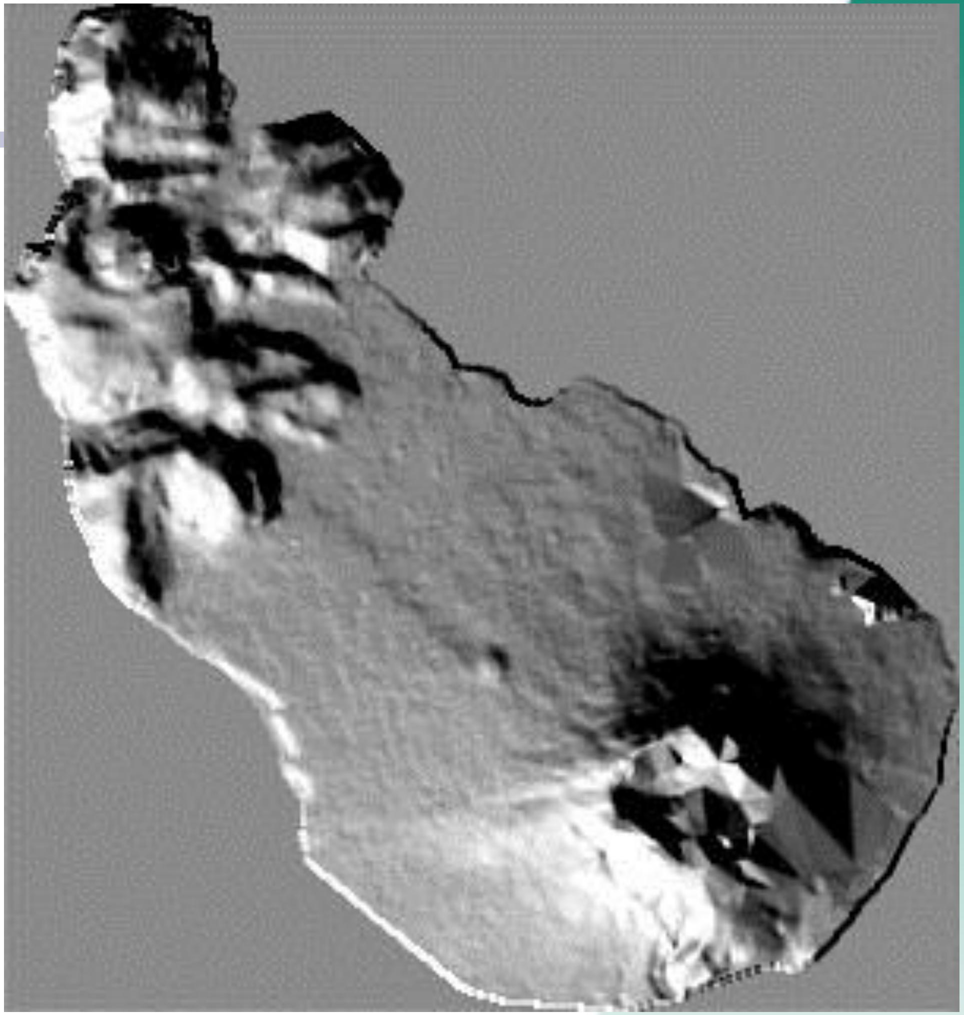
Topographic map

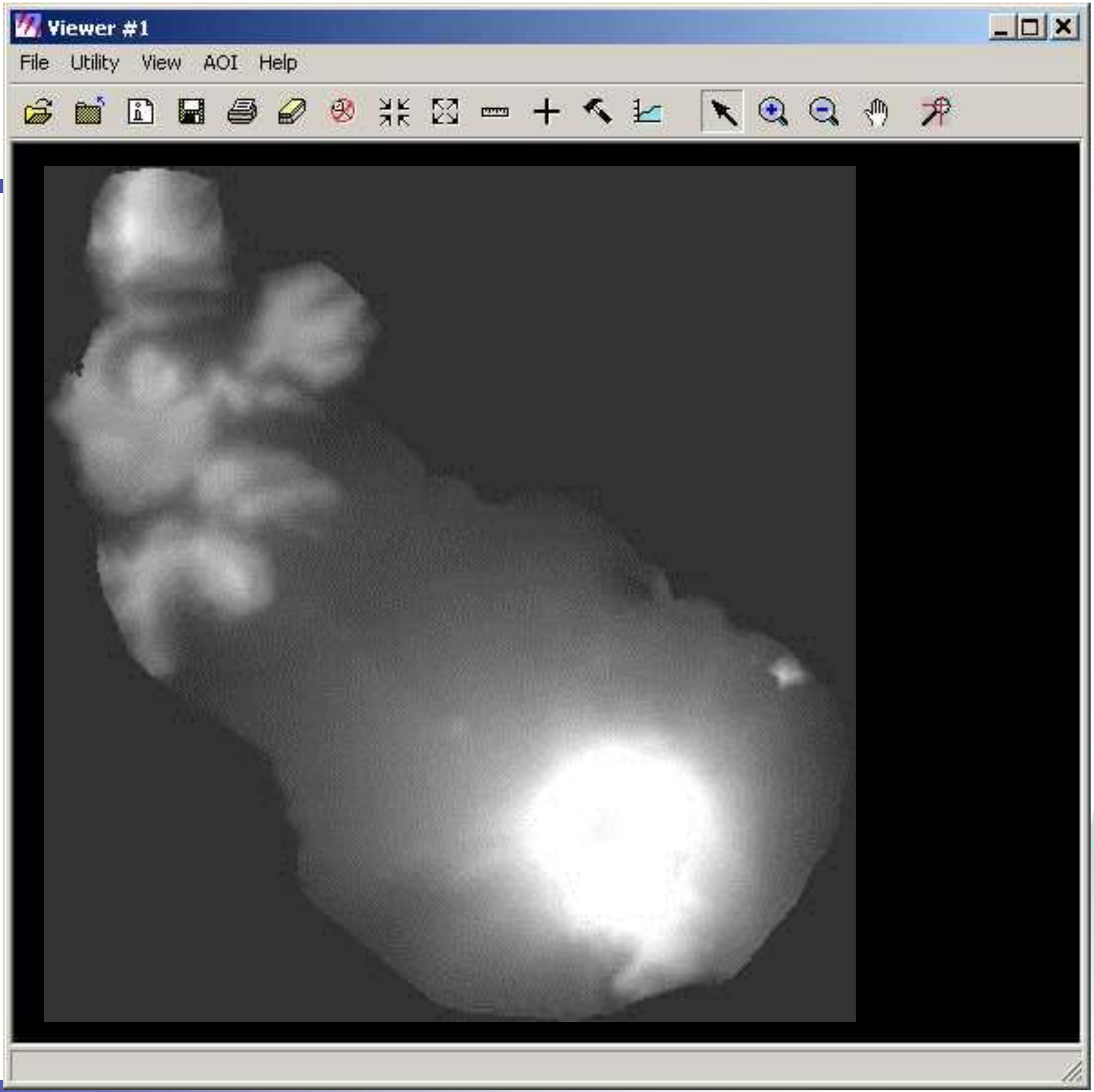


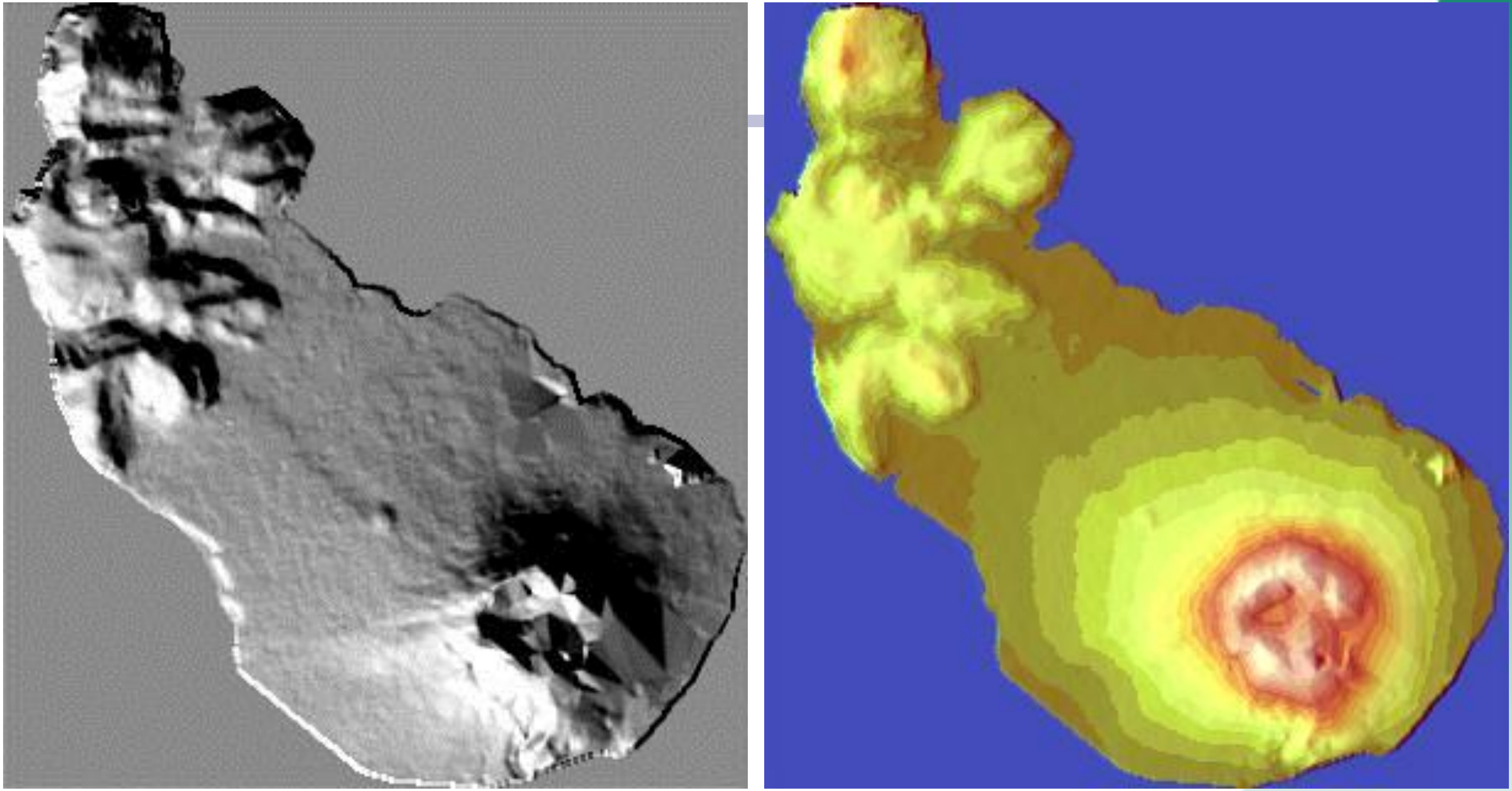
Orthophoto

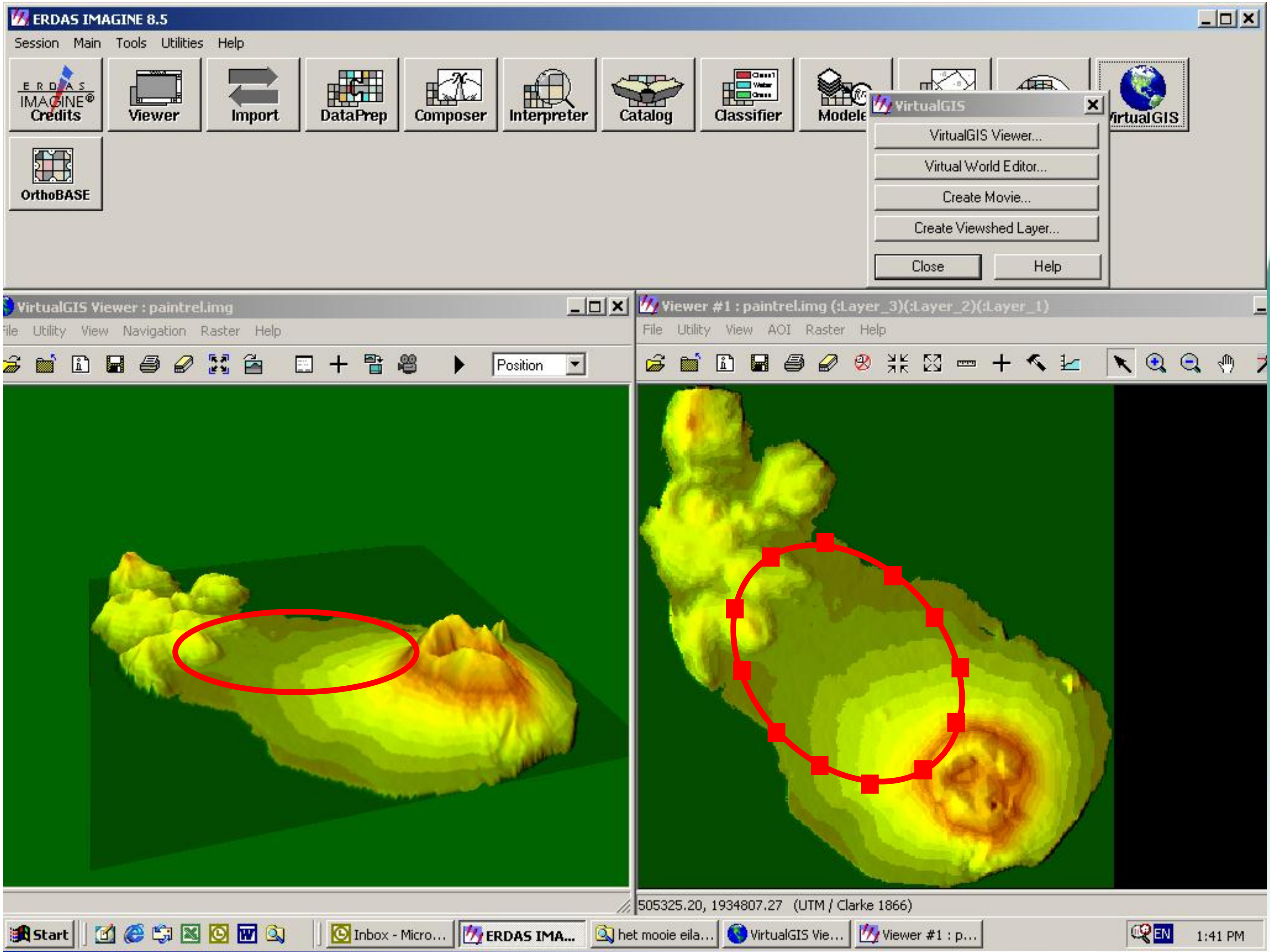




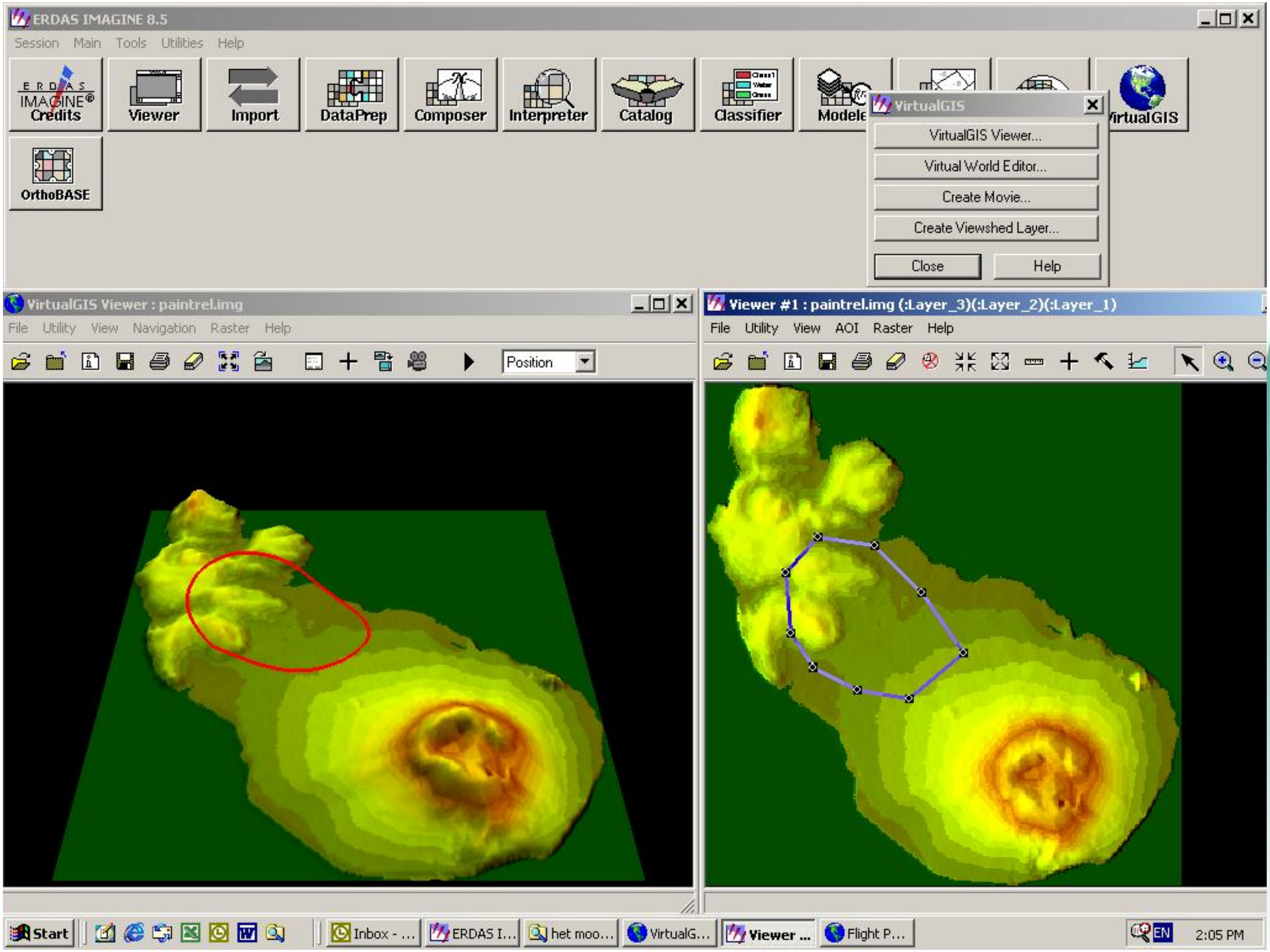



Viewer #1
File
Utility
View
AOI
Help





505325.20, 1934807.27 (UTM / Clarke 1866)


ERDAS IMAGINE 8.5
Session Main Tools Utilities Help
ERDAS IMAGINE® Credits
Viewer
Import
DataPrep
Composer
Interpreter
Catalog
Classifier
Modeler
VirtualGIS
OrthoBASE
VirtualGIS
VirtualGIS Viewer...
Virtual World Editor...
Create Movie...
Create Viewshed Layer...
Close
Help
VirtualGIS Viewer : paintrel.img
File Utility View Navigation Raster Help
Position
Viewer #1 : paintrel.img (:Layer_3)(:Layer_2)(:Layer_1)
File Utility View AOI Raster Help
Start
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